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RC Baja

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R/C Baja

By

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Abstract:

American Society of Mechanical Engineers (ASME) hosts an RC Baja competition yearly at Central Washington University where schools from around the state gather to compete. The competition is based and scored from three different events: drag race, slalom, and a Baja course. Performing well in both the competition and other various tests will deem the car successful. The differential and drive train are two important features that allow the car to function properly. Using Solidworks 3D software and a 3D printer, the engineers were able to design functional components. The differential is designed to allow the rear wheels to spin independently of one another. In corners, the rear wheels can rotate at different rates while still receiving input to accommodate for the different turning radii. In addition, the drive shafts can handle a scaled torque of 376.3lb-ft without failing due to torsion. A 7-gear system was implemented for the differential with 6 gears inside and a ring gear molded to the outside allowing for a compact design. Speaking to the overall weight, a fun fact about the car is that it only weighs 5lbs completely assembled due to a lightweight wooden chassis design. This design was meant to be an innovative change from the more common aluminum chassis. Every aspect of the car was built and assembled in a way that will allow a rapid repair if necessary while still adhering to the ASME guidelines.

Contents

1. INTRODUCTION

a. Description

The main issue involving the RC is the differential. It is probably the most key component of the entire car. It must be able to allow one wheel to spin at a higher rate than the other while still receiving the same input from the motor. It is this function of the gearbox that will be the most useful for the car's functionality as well as personal knowledge. Engineering will make this possible through calculation of different gear ratios and gear angles.

b. Motivation

A problem would be allowing one wheel of a car to spin faster than the other when turning a corner. Thus, the need for a differential. The motivation for something like this could be decreasing accelerated wear on tires by preventing them from having to slip or skid around a corner, and rather rotate like normal just at a different speed. This is needed to increase the longevity of the motor and car itself.

c. Function Statement

- Differential: The purpose of this part is to allow one wheel to spin faster than the other while both are still receiving power.
- Differential Housing: Protect gears and hold them together snug as well as being watertight.
- Transmission: Allows a conversion to a gear ratio that is useful for the job at hand
- Transmission Cover: Keep gears in place and dry.

d. Requirements

Differential:

- Gears inside differential must be able to spin at a 3000-rpm difference
- Should not surpass temperatures of 50 degrees C from friction
- Car must be able to withstand acceleration from 0-30 mph within 30 ft

Differential Housing:

- Able to withstand friction from rubbing up to 10500 rpm where gear rod touches the cover from the inside of housing
- Should not be larger than 2 inches in diameter with outside gear attached
- Cannot be purchased at an RC shop

Transmission/Internal Gears:

- Must have no more than 2 gears inside the actual box.
- Gears will be smaller than differential gear
- Can be but is not pertinent that it is comprised from toy sets

Transmission Cover:

- Needs to be able to double as a motor mount
- Dustproof

- Needs to be made from erector or alike set

e. Engineering Merit

There will be many testable aspects of the Baja including in this case, torque of the motor and how it affects the gear up to the differential. Showing adequate skill for calculation in this will prove to be useful for later analysis. The differential needs to be engineered because without it the car would have what is called a locked differential. which will put far more load on the motor, increasing the potential of failure. The other team members perhaps have the more practiced calculation to work with such as stress, strain, and bending moment of parts like the A arms. Success in these areas will keep the car together and working.

f. Scope of Effort

The differential is the product that needs the most attention. It is the most important aspect of the gearbox because it is what connects directly to the drive shafts. Since the motor cannot directly connect to the differential, the gear up components are the second most vital of the parts required for design. The focus of this project will mainly include the differential and gearbox seeing as how they are a large part of what makes the car run properly.

g. Success Criteria

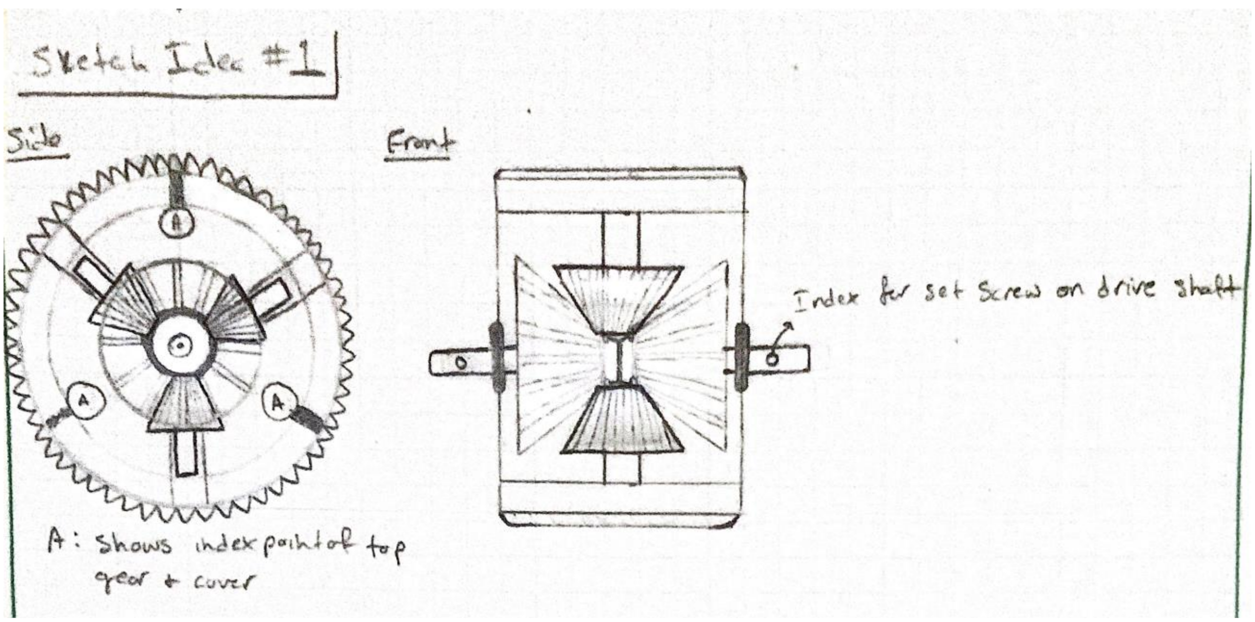
- Differential: One wheel continues to spin if user holds the other while still receiving input and completing the course without locking up.
- Differential housing: Gears stay in place and apart from each other. Completes course without gears inside differential contacting other gears they aren't supposed to.
- Transmission/Internal Gears: Gears are mounted close enough together so that only a piece of paper can be threaded between them. Gears complete course without stripping out from torque.
- Transmission Cover: Keeps gears and bearings in place so that they have no slop right or left. Gears stay in place and snug against each other until completion of course.

2. DESIGN & ANALYSIS

a. Approach: Proposed Solution

The design stemmed from previous knowledge, online research, and other RC models. A video made by GM motors described the requirements and function of a differential. The designs that were chosen involved a range of gear amounts, some had four and others, six. For this application either option will work just fine; however, the five gear will be simpler to assemble. The five-gear option is the front runner for the differential design. Besides the differential, other components are being changed to wood to improve on the power to weight ratio. While this may take more time, it will cut the cost of the project as a whole.

b. Design Description



c. Benchmark

Traxxas is a great example for Baja type RC's and it most likely will be what this project will be modeled partly after. It is expected that the RC built in this project will not be as durable as the one made by traxxas due to design and accessibility restraints as well as cost. However, there is no reason that the model cannot go just as fast as the benchmark. From experience, the traxxas has a good weight balance for the two-wheel drive versions, but it could be better. This is something to see about improving on the model. All in all, the model RC should be able to withstand all the wear and tear of tough terrain just like the traxxas is able to .

d. Performance Predictions – related to requirements

The car itself will go at least 30mph. The RC will be waterproof, able to go through any terrain in the course and more and not get stuck. Run time on a 2 cell 5700mah lipo batterie will be at least 30 minutes.

e. Description of Analysis

The RC Baja has many vital parts of it that make it useful for what it does. For example, if the hubs are not made from a strong material they might deform upon high torque and lose a wheel. The overall objective for this project is to have the RC hold up over the entire course without failing. All components must do their part for this to happen. In specific, for both functionality and grading purposes the differential requirement is that is allow one wheel to spin faster than the other while still receiving the same input from the motor. For this to happen the differential design must be sound as well as the differential gear must be able to handle lot of random changes in torque in all different amounts. This is because if both wheels have the same amount of traction then the differential is essentially locked meaning that none of the gears inside the differential are moving, just the single gear on the outside connecting to the rest of the transmission. Analysis was done to calculate torque in part of the system; however, it was found that all gears needed to be steel or something of similar strength to withstand torque. The amount of torque was surprising, so the design was altered to consist of a gearing up section to relieve some torque on some gears.

f. Scope of Testing and Evaluation

baja, slolom, and drag race.

g. Analysis

i. Analysis 1

The first analysis consisted of the pinion gear coming from the motor and the next gear in line which is being named the spur gear. For this, the spur gear had to withstand a 3700kv rated electric motor spinning at 40000rpm. The gear up in this part is the most important for the 'transmission' so it had to be substantial; therefore, the gear ratio needed to be at least 4.5 with a limit of 6. It was calculated that the torque applied on the spur gear was 45157.66lb-in. Since this RC is a scaled down car, the chosen scale was 1/10. A calculation was performed to relate this to a real-world application, it was found that a normal car would have 376.314lb-ft of torque comparatively. This happens to be in the range of the torque of high-performance cars which have metal gears all around. After choosing two different materials, A-36 steel and Kevlar 49, the Poisson's ratio was compared for each material. The results were that the ratios were 0.32 and 0.34. This shows that the plastic (Kevlar) would be harder to fracture than the steel. As this does not relate directly to the amount of torque it can withstand before deforming, it gives a good general idea of how strong each material is. Hence, a relief angle of 20 degrees was chosen to deal with the increased amount of torque. In Appendix A-1, all calculations and diagrams are shown that correlate to the numerical values provided for this analysis.

ii. Analysis 2

In this second analysis the material of the differential gear housing was researched to find a specific combination of plastic, metal, and adhesive that would work well together. The differential gears inside the housing are find without being glued in place, but there needs to be a gear on the outside of the housing to connect to the other gears in the transmission; it must be glued on. The analysis was based off strength and then temperature. At first, a list was made of each category to see what types of each there were out there. Then, as a personal preference, two options from all categories were chosen and researched. Plastic is being used for the differential housing itself and the two materials chosen for that were ABS and Kevlar. Metal is being used for the outer lying gear on the differential housing, steel alone was chosen for this since it was already decided that steel was going to have to be used for all gears to withstand torque values. To mold the previous two together, an adhesive must be used and one part, as well as two-part epoxies were the front runners. After choosing materials based on strength, a temperature rating for each was needed. Not so much for the wear temperature, but to make sure all materials could withstand the curing process of the adhesive. Kevlar can withstand almost 400 degrees C more than abs, but it does cost a bit more to buy. Steel is almost a given that it has higher temperature properties than most plastics at 870 degrees C melting point. The adhesives were the important part: one-part epoxy cures anywhere from 100-150 degrees C, and two part cures anywhere from 24-30 degrees C. Two different options were concluded from this: it either had to be ABS/STEEL/TWO-PART, or KEVLAR/STEEL/ONE-PART, due to heat restrictions and fear that the plastic might deform during the curing process. Based on these assumptions, it is assumed that the car will be able to withstand the amount of heat caused by running two fully charged Li-po batteries without even coming close to melting anything or rendering them ineffective.

h. Device: Parts, Shapes, and Conformation

Starting with the first part, the differential housing. For this part there was no safety factor implemented, it was not thought to be necessary because of its shape and purpose it wasn't a high stress part. The components that it will drive will have tolerances due to the high torque produced by the gear. The shape of the differential housing is based from a different RC differential off a name brand RC company. The dimensions were produced after finding gears that would be useful for the application. Extra room was left in the differential housing jut incase the gear diameter was too large. Spacing of the gears was a hard concept to get right. There was a lot of interference in the beginning and most of the gears would touch each other, so the dimensions and spacing of the mounting points of the gears inside the differential were changed. The pin part for the inside of the differential gears doubles as the part that the wheel hub will index on. A safety factor was added to this of 1.5 which was only for the wheel hub since there is little to no stress that will be applied when the pin is inserted in the differential. This was used to increase the diameter to 2mm since before the safety factor the pin was almost non-existent for the material chosen. There were no safety factors added to any of the gears inside the differential due to the material of the gears that will be purchased. The shape of both gears was simply modeled after the gears that were found that are going to be bought. Dimensions were measured and rounded by approximation because the gears were not exactly labeled with relief angles, Pd, gear diameter, etc. They were designed as close as possible and then edited to fit in order to create an animation without interference. The hex hub was also not given a safety factor. The part will be a plastic on plastic connection in the full assembly which will not be a problem. The shape of this part was determined by the shape of the wheels chosen which have a hexagonal index connecting the two. The only issue when designing this part was the rounded edges inside being possible points where the hex could slip out since the design of the pin was now changed to not be rounded at one end. Nothing was changed to account for this since the lock nut securing the wheel will be enough pressure to press the hex in place. Later, the gear surrounding the differential may be excluded since a different type was found online that can surround it almost perfectly and it will match up to the other gears that are being purchased. The gear should be metal around the differential since it is a gear that needs to stay intact and not sheer.

i. Device Assembly

The problem proposed for Ryders part was to design a differential. Some of the requirements were for speed, and of course, functionality. The differential was to allow one wheel to spin freely while the other was stationary at its most extreme circumstance. This problem was solved by the differential created. In this, there are 6 different gears inside, two being the gears that drive the car and the other four performing the differentials initial job. The way it works is that gears diagonal from each other are touching; however, each middle gear is only touching two other gears. The gears on the outside that only meet one of the middle gears, are touching each other, but are offset so that one of them doesn't touch the middle gear that the other is touching. This way, the whole of the differential itself can continue to rotate as one set of gears isn't moving, nevertheless, the other gears can rotate around the gear not moving to allow the car to still receive input from the motor and move forward.

j. Technical Risk Analysis

Some risks of the car happen to be with the gears, the chassis, and the mounting points for the suspension. The RC does not have to be a certain size or meet any weight requirements, but it does have to complete benchmarks. One of those being a drop test, the suspension will have such a small mounting point and the a-arms will be printed, so, they will have to be able to support that distance without shearing off which is a very real possibility. The A-arms may have to be made thicker to support this. There is one gear in the whole gear train that will be plastic, and that gear is "the clutch gear". It is the gear that has been chosen to be the easiest to break due to its ease of access as well as its low ranking on the importance level. It is the most expendable part of the gear train and the easiest to replace in case it decides to shear off some of its teeth. The chassis is going to be made from wood, naturally wood wears more quickly than plastic does even if it is resin coated. It will need to be made sure that all the holes made are the right size so that it does not have to be taken apart or the wholes re threaded many times to reduce wear on the car before the tests. The chassis most likely will not be able to be recreated very quickly so the act of doing so will greatly detract from the timeframe for building the model.

k. Failure Mode Analysis

Some types of failure involved with the differential and its gears would be fatigue, dynamic, and shear stresses including normal stress. The gears aren't all made of pure steel, a few are some sort of composite along with steel that is both lightweight and effective while allowing for the gears to take the hit occasionally instead of the motor being overloaded. These stresses were calculated in the later analysis in appendix B and were found to be quite high if the motor is running straight from 0 to full throttle at whatever rpm that happens to be. This was the reason for adding a plastic gear just off the pinion so that if the torque was too much for the gears, then the plastic one would shear first and could be easily replaced as opposed to the internal gears where the whole transmission housing would have to be removed from the chassis and taken apart.

l. Operation Limits and Safety

For this project there are not many limits. In general, to extend the cars lifetime is would be advised that the driver not have whiskey throttle which would apply an unreasonable amount of torque to the gears that is most likely unnecessary. Furthermore, the tests such as the drop test should only be tested two or three times before the actual competition as to not put the extra wear on the car as well. The car should not be used to tow anything as it would be putting too much extra load on the motor which may compromise its sustainability.

3. METHODS & CONSTRUCTION

a. Methods

The project will be designed on SolidWorks while keeping in mind the restraints of CWU's resources. The construction of the transmission, gears, differential cover, and drive train will occur in Hogue and at CWU. Parts like the chassis which is being constructed out of wood will be manufactured in Hogue as well in the woodshop.

i. Process Decisions

The first step is to construct the chassis. To do this, CWU's woodshop will be utilized using tools like the ban saw, planer, drill press, belt sander, and router. Holes will need to be drilled in the attachment spot where the A-arms are to be mounted. The planer will be used to get a flat and parallel surface on the chassis. The belt sander can be utilized for touch up and hand sanding for around the smaller parts for detail work. For appearance, the router will round all edges to provide a smooth edge. The ban saw is what is going to be used for all the detail cuts, mostly including the A-arm to chassis mounding points and extensions in the front and back for the shock towers.

The second step will be to add the shock towers which are going to be 3D printed in Hogue at CWU. They will need to have holes drilled into them for mounting points on the chassis. Then, holes will need to be drilled into the A-arms for mounting points for the shocks. They will need to be drilled 0.5cm into the a-arm to be able to withstand the force without shearing. The suspension towers designed by Jeffery Harn are to be mounted directly in line with the a-arms/drive shafts to get the best travel from the springs. Also, having the suspension mounted at an angle will cause unneeded stress concentrations on the edges of the a-arms which are already very thin pieces of material. To accommodate for this design, the gear box will be flipped or rotated so that the motor is facing in towards the center of the car rather than at the very back edge. This will still allow the drive shafts to be perfectly in line with the wheel hubs, while also shifting the weight balance more to the center of mass of the chassis which is an improvement. Changing the placement of the motor allows a section of the rear flange on the chassis to be placement point for the suspension tower, making it right in line with the rear a-arms. Front mounting will not be such an issue since there are no components that occupy the front part of the chassis.

Third, the differential and internal gears are to be mounted inside the transmission cover designed and manufactured by Jeffery Harn. Then, mounted to the chassis designed by Naoki Masuda and connected to the drive shafts via a 2mm set screw.

Finally, the electronics such as the motor, speed controller, steering servo and receiver pack are to be mounted to the chassis. Originally, two separate steering servos were modeled to be used, one for each wheel; however, after looking into the matter, one servo will be plenty since there is not much leverage from the wheels. The motor pinion will need to be properly adjusted to be spaced just far enough away from the clutch gear that one piece of paper is able to be fed through successfully.

Pictures will be added to this section as the manufacturing commences. For now, please refer to the drawings in appendix B.

b. Construction

i. Description

The RC will be built in phases. Since most parts are already in the hands of the manufacturers, a good amount of assembly can be done already right off the bat. The biggest part will be the chassis since it wields every other part that is a component of the RC. Once that is complete, the a-arms, drive shaft, wheel hub assembly and camber arms will be added. Holding off mounting the wheels will allow for more space and versatility to mount all the electronics so the wheels and tires will be mounted last. Next will be the steering servo because it is the most complex component to place and get right. After that, the rest of mostly plug and play as far as electronics go. Some weight balancing will need to be performed to reduce having too much force applied to one side during the drop test. The car will be 2wd meaning the motor is going to be in the rear of the car focusing most of the weight to the back.

ii. Drawing Tree, Drawing ID's

The first part to all assembly's is buying all the materials in order to manufacture and then assemble. Starting out, the housing for the transmission/gear up section will have top be made before all the gears and differential are made. Both the transmission housing and differential housing are going to be 3D printed in Hogue. After these are manufactured, the gears are to be added to the inside of the differential and then that will be mounted to the inside of the transmission cover. From there that whole assembly will be mounted to the chassis as stated in appendix B where a completed drawing tree can be located. The separate assemblies such as Naoki's and Jeffery's are moderately simplified due to them not being the focus of this proposal. Naoki is doing the chassis which will need to be completed with all its mounting points before any other component is mounted. Jeffery's section will need to be completed before the differential housing since the transmission housing is what wields all the gears. The rest of Jeffery's section will be printing the shock towers and mounting them to the chassis along with the suspension that connects directly from the shock towers to the a-arms.

iii. Parts

The parts list in appendix C includes a list of both manufactured and either bought or pre-owned parts. The parts to be bought are mostly from the popular RC car brand 'Traxxas', although the motor and speed controller will be purchased from 'Castle Creations'. The parts that are being manufactured will be printed on a 3D printing machine. Some Parts including the chassis and suspension tower will be made using balsa wood and resin to harden them. Most parts that are being printed on the 3D modeling machine or resin casting machine will be to spec right out of the mold. While other parts such as the ones being made from wood will need to be trimmed from their 3 ft stock pieces.

The first part being constructed is the differential, the focus. The design was remastered to include a more educated clearance fit for the top cover of the enclosed gear box. To make this part, use of a 3D printer is in order utilizing left over material in spools that the lab already has.

Preferably, PLA plastic would be used for printing because of its more ductile qualities as opposed to ABS which has much more brittle qualities. After the printing of the differential housing and top cover, the machine shop will be used to create countersinks, chamfers, and to clean out holes with a reamer if needed. For the top cover, each hole that is aligned for the screws will need to have counter sinks because of the shape of the screw head. Threading the holes for the specific screw being used will be attempted; however, since it is difficult to calculate how the material will react, it may be just as productive to pilot them in. After the holes are finished for the screws, a test fit must be made for the pins holding the gears. These holes must allow the pin to be fully inserted when the top cover is seated on the housing. If this is not the case, the problem will have to be fixed by either altering slightly in the machine shop or reprinting one or the other. This will be the only part that is being printed since most of the other parts are gears and will be purchased. There will be a secondary option for the gears since they were created in solid works and this is to resin cast them. There was little to no analysis done for this because it was determined that they would shear at the lowest amount of torque required for the car to take off at a moderate pace.

iv. Manufacturing Issues

Issues that may arise during manufacturing will be documented as they occur. Some possible issues that could arise would be in the woodshop, over cutting could be an issue that would cause delays in the manufacturing process. For the 3D printing, any one of the designs could be off by a small tolerance and not fit with the whole assembly. A hole can be bored out to be bigger and a length can be shortened a small amount but either of these processes can be reversed. This could cause a minor setback in the manufacturing process as well. The most tedious of all being the differential, if it is off by even the smallest fraction, some gears may touch that aren't supposed to and some may not touch that are supposed to which would call for a revision ad another printing. One of the issues that had happened with the gear box was that one side printed wonky and isn't completely flush with the other side of the housing. A reprint could be in order, however with the amount of machining required for the one side, dealing with it how it is may be acceptable as long as everything lines up.

v. Discussion of Assembly

For starters, lets separate the RC into sections: chassis, drive train, gear up/transmission, suspension, electronics, front assembly, and rear assembly. The chassis is exactly what it says it is, it is going to be manufactured and that is all will be. It is just a housing unit for all the components of the RC. The transmission is its own assembly containing the two gear up gears, differential and clutch gear, all of which will have to be assembled before it is mounted to the chassis. The drive train can be looked at as either an extension of the transmission or the hub assembly, but either way it must be connected before the transmission housing is mounted to the chassis. The "rear" assembly is essentially what was just described by the drive shafts and gear up section, it must be mounted before the wheels are mounted but after the hub assembly is configured. Next is the front assembly which includes the from steering hubs and steering servo. Both the front and rear assembly's must be configured before suspension is mounted to the RC otherwise the suspension could get in the way making the process more difficult. Aside from assemblies, the electronics as stated before are a mostly plug and play type of procedure where the motor will be connected to the speed controller, and the speed controller as well as the steering servo will both be connected to the receiver pack which is then remotely connected to the remote control. There is some leeway in what things can be attached first, but for the most part all assemblies will need to be complete before mounting and all mounting has to be done when it can still be easily accessed without other components getting in the way. The prediction is that the assembly of the parts in the whole configuration will be functional. The shock towers will be able to withstand the four-foot drop, the differential will allow one wheel to spin while the other is stationary, and the car will be able to reach a speed of 30 mph in a 20-foot span.

4. TESTING

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a. Introduction

The testing methods will meet the specifications of some items listed in the requirements section, and some from the analysis section of this document. There will be at least three tests, more will be added depending on the results from the previous tests. The first requirement is that the differential do its job, one wheel should be able to spin while the other is not no matter what the rpm. The second test is the speed test, in Appendix A-5 the requirement states that the car will need to reach a speed of 30 mph. This requirement is relevant to the “Slalom-and-Sprint” part of the competition where the car will have to accelerate and reach as high a top speed as possible in order to complete the sprint faster than the other cars. Third and final will require that the motor not reach a temperature of above 50 degrees C after being drive hard for a full batterie. This temperature is the melting point of the plastic being used and if that melts the motor will fall out of place and the entire drivetrain will be compromised.

b. Method/Approach/Procedure

As stated before, if the test results are not satisfactory more tests will be done for the same components to ensure the parts will meet specification. For the first test, one of the partners held the RC from the rear with one hand on the chassis and the other holding either wheel in place. The other partner then gradually applied full throttle to the motor and made sure that the differential had no problem spinning one wheel over the other. Lastly, mid test the partner holding the car released the wheel making sure the differential would then disengage allowing for both wheels to spin together.

The next requirement was set up on the same course used in the actual competition. Two cones were placed on the floor 30ft apart for the sprint test. All partners performed this test to ensure the car reached a speed of 15 mph at least before the cone. To do this, one partner drove, one timed, and the other used a radar gun aimed at the ending cone to record the cars terminal velocity at that point. This test was repeated two more times with each person getting to do each task once.

Lastly, to test for the motor temperature and ensure that there would be no issues the group decided that a high factor of safety must be employed. Putting numbers aside, the requirement was that the motor not reach a temperature of above 50 degrees C after the car has been driven for 10 minutes at 10-15mph. The team decided that to make sure it would not fail during the competition; 3 trials were to be done. This triple test was performed only once as to not put the motor through too much stress before the competition. After that, it would be clear whether the car would survive the trials and score under the 50C requirement.

c. Deliverables

Appendix G has the test results from each test performed on the drivetrain focused testing portion. These tables will be filled out in the spring when the testing is performed. Analysis will be done on the tests and compared to the original requirements to see if the RC meets the standard.

The first test for the RC Baja was a temperature test. The parameters were that the car be driven for 10 minutes between the speeds of 10 and 15mph, then, check the temperature after each trial and wait five minutes to start the next one. This test should have three trials in total. The prediction was that the car does not reach a temperature of 50 degrees C after each trial. The determining factor for this was that PLA has a melting point of around 150-160 degrees C and being anywhere near that temperature could be detrimental to the integrity of the car. The biggest fear was that it was not clear how the stress of the motor would affect the material after it had been heated to a temperature close to its melting point. The material could start to deform which would compromise the transmission housing itself and possibly causing the motor to fall out of place.

The results were satisfactory to say the least. The car performed well during each test; however, after the second test a repair had to be made causing the third test to start later than scheduled. That being said, it did not affect the testing procedure in anyway and the evidence can be found in appendix G under the first testing procedure. The car did not run as smooth as it could have, there are some wear spots that are being looked at fixing. These wear spots cause more load on the motor and more stress on the gears which should cause the motor to heat up more during use, this was not the case. The motor running at that speed for the duration of time listed scored much lower than it should have. This is most likely because of the type of driving since it was holding one constant speed and not starting and stopping constantly like it would in the Baja course. Although this may have not been a specifically accurate test for the Baja course, the car will not have to run for that long or at that speed during any of the tests in the competition. From this it can be determined that the car will not overheat during any of the competition.

The data collected is in two columns: one for time, one for temperature. Truthfully, only temperature was needed because it is stated in the instructions to test for ten minutes and then rest for five minutes, then resume and repeat three times. Time was added due to a repair that needed to be done after the second test that took over ten minutes causing the last test to start later than originally planned. This was to represent human error in any test. It can be seen that it did not affect the data whatsoever, but it was a problem that could have affected the data so time was then added to represent the overall time elapsed throughout the entire testing period. From this it can be gathered that test three started around 6-7 minutes late as can be seen from the ending time being over the 45 minutes that should have been the final time had everything gone according to plan.

The Second test performed was the acceleration test where the team would see if the car could reach a speed of 15mph in 30ft. The test went poorly on the first test due to the steering being off and the car hitting yet another wall, ripping the a arm from the chassis once again. The car was repaired, and then further trials were done that were 100% successful. The original requirement was 30mph in 30ft but this was quickly changed after seeing that the car at full bore was not able to even make 20mph. The car was able to make 15mph however, it did that speed very successfully multiple times over. Some things that should be changed are making stiffer front camber and steering arms stiffer and/or more adjustable. After impact the front wheel was cambered much too negatively causing the car to steel very aggressively with any slight input. Overall the test was successful in showing the cars ability to accelerate in rapid succession in a short amount of time. The data showed that the cars top trial was 18mph which was the trial that it had crashed in. This shows the instability of the front end and how at speed it is difficult to control. The test was deemed a success with the car meeting the adjusted requirement and staying in tact after the repair.

5. BUDGET

a. Parts

Some of the items in the table in appendix C like the motor and bearings are going to be expensive comparatively. Together as a group, Naoki, Ryder, and Jeffery all decided to split the cost for everything instead of only buying components that the individual was responsible for. In the table there is a full list of all the parts that will need to be purchased as well as how many of those parts that will be needed. The motor initially was going to have to be purchased but Ryder was able to fine one that would work for the application so money will be saved there. There was going to be an issue ordering overseas with COVID happened and all but so far, all orders have arrived and shipped rapidly. Most of the low-cost parts are already owned by Ryder such as the nuts, bolts, clips, body pins, and wheel hub NY locks etc. Parts left to obtain include some washers and one more pack of 2 bearings. Other parts may be added as the construction is completed; however, this will most likely not be the case. During Construction, finding camber arms, control arms, and steering arms was quite difficult since it would have been nice having them all be adjustable. Finding ones that were too short was the issue but finally after lots of online searches the team found some that would fit with the hardware chosen. After finding these, 4 were purchased just in case a longer one was needed for a different section. The company ended up sending the wrong a-arm and with time restraints, the products had to be modified to work and they were. Besides this hiccup, another part that was thought to only be needed for the wheel hubs were the bearings. In fact, the car needed almost 25 bearings in total to fill spaces in the transmission and make everything run smooth. This se the team back slightly because of the wait time for the bearings, price was not an issue. To prevent these mistakes in the future more planning would go into exact measurements so that could be a criterion for a web search rather than just buying ones that said they were universal fit.

b. Outsourcing

For some parts including A-arms, differential cover and transmission cover, a type of outsourcing will need to be done. The differential housing, gearbox, a arms, shocks towers, and batterie cover were all sent to professor pringle to be printed in the maker bot 3D printer. No other outsourcing needed. The printing would have affected the budget in a deficit but instead CWU already had material to print with, so the team saved money by printing through the school. Most rolls of MakerBot or standard pla range from $60-$400 depending on the roll or quality of material. In the end this saved approximately $120 for the specific material that was being sought after.

c. Labor

Most of the work will be in the hands of the team members. For outsourcing, all the person receiving the file must do is put it and the material in the machine and it will take over from there on out. Labor for team members includes using the woodshop to form the chassis, (originally the chassis was going to be covered in resin and put into the silicone vacuum chambers; however, this is not feasible anymore so it will instead be coated in polyurethane to make it water resistant and add rigidity), then using the machine shop, and ceramics lab to make any modifications to the parts afterwards.

d. Estimated Total Project Cost

From the budget in appendix C, with the parts that are needed so far, it can be estimated that the total cost of almost all parts will be around $170.00. This price reflects everything priced without tax, so currently the budget set for now is $350. This budget allows $200 for parts, $100 for material such as wood, 3D printing plastic or resin, and a $50 cushion just in case more is needed, or a part is broken during the process. Further updating will need to be done to get a firmer total price. For example, the type, length, and price of wood for the chassis has not yet been determined. In general, the price of parts has almost reached the desired budget maximum and all parts are purchased for the most part. The total spent so far is $166 which is not even half of the budget, yet it almost matches what the estimated cost of all parts would be after purchasing 90% of parts already. All parts are mostly here and all will be on time and won't slow down the time line.

e. Funding Source

The funding for this project comes directly out of the pockets of the team members. The team did try and contact traxxas and ask for a sponsorship, but they have yet to respond. Each team member is splitting the cost three ways and providing anything previously owned that might work in place of another purchase to reduce cost.

6. Schedule

a. Design

The full schedule for this project can be found in Appendix E. The schedule is separate by month and has approximate deadlines for when each section should be finished by. The most important deadline however will be the testing day in spring, of which the date is unknown. This is due to not knowing if the event will be in person or virtual. All designs for the differential will be done by November 15th. Any other components that need be design will be completed before this date as well. After this point, any alterations made to designs will be listed as changes to the existing drawings. Parts that will be purchased overseas need to be thought about and purchased much in advance as to not get set back because of shipping times. It is estimated that around 85 hours will be spent for the design portion of this project. There have already been a few setbacks, for example a gear assembly was drawn in ANSI inch instead of mm and the whole assembly had to be redrawn. This leads to a projection of around 250 hours spent throughout the entire school year.

b. Construction

The construction portion of this project occurs during winter quarter roughly between the months of January and march. This is the manufacturing and assembling stage of the project. During the printing of the differential housing and top cover, some issues arose. It became clear that tolerances were not calculated for properly spacing wise, so a redesign and reprint were in order. The gears would mesh with each other, but they would hit the very thin wall on the inside of the cover which could not be cut away due to it being 1mm thick. This, along with COVID setting the schedule back two weeks already, set the assembly of this part back just one week. This was not a big deal since other group members are still manufacturing parts. A deadline set for full assembly of the car is February 12th. This timeframe will give the team enough time to make changes if needed and/or redesign if a part does not fit. Full working machine will be completed and ready for testing by the end of February at least. An average of 73 hours has already been spent on this project and it is projected that another 20-30 will be spent this quarter alone on the assembly.

c. Testing

Following the construction of the device comes testing where there are a series of tests deeming the car a success or not. As the first test was taking place, the temperature test, bolts holding the differential together had no material to thread into due to the 3D printer not being able to infill. As this was not a set back since the repair only took roughly 20 minutes, it did call for a re-test and reprint which added to the overall testing time. Due to time restraints, retesting would not be taking place until after all the testing is done to save time. During the second test, acceleration, the first trial had the car sent into a wall which fractured the A-arm at the chassis connection. This too was fixed on scene with only 20 minutes added to the test and testing was also good to be continued that day. Third and final test was the differential test where the goal was to simply check if it was working properly by moving the wheel separately from one another. This test took little time at all and provided more time in fact for the retesting of the first test. A total of around 12 hours was spent on the entire testing process encompassing all 3 tests. The original deadline of April 23rd was not achieved, testing was completed by May 4th. More time will be utilized in the future to produce the reflections on these tests to the website.

7. Project Management

a. Human Resources

Things that the group will have to rely on will be professors Pringle and Choi due to them having access to the shops in Hogue in which the group will create parts and/or print them. This shouldn't be too much of a risk as the printing will happen on its own and the woodshop stuff is the only section that will take the longest amount of time. The risk is to be managed by getting on top of the manufacturing part early in the quarter so all that is left will be assembling and possibly tweaking a couple designs any given part.

b. Physical Resources

Physically, the group will need access to four of the labs in Hogue: machine shop, wood shop, metals lab, and the 3D printing room in between the two 3D modeling labs. Knowing that this year there are multiple teams doing the same project, more people will be needing to print so the goal is to have everything the team needs to have printed up and ready as soon as the quarter starts so just in case the part is not the right dimensions or there was a wrong calculation, it can be fixed and reprinted before it's too late. Also, the team is going to need to be trained and certified in some of the tools in the woodshop to complete the creation of the chassis. Other teams doing the bridge project will be needing the woodshop as well; however, there should not be an overcrowding problem with this lab since most of the components for that project are rectangles. If there is overcrowding of the lab and it is unavailable, then there will just be a days' worth of setback in which can be made up for by spending more time in the lab the next day.

c. Soft Resources

SolidWorks will be a requirement; however, both Ryder and Jeffery have the app downloaded to their computers at home, ready to access whenever so this should not be an issue to modify designs. If all else fails, the computer labs at Hogue are always open during the week and are never full of people. Other than that, the only thing needed would be email so the team can email the parts that will need to be printed to Professor Pringle to be printed. The risk with Pringle being a go between is that there might be a delay from when the part file is sent and when it is put into the machine to be molded. This would cause a minor set back in schedule but would not cause an issue if done early in the quarter, working out all the bugs early.

d. Financial Resources

The team emailed Traxxas, a well-known RC company that is supplying most of the parts that are being purchased for this project. They have not responded yet. As of now, the team will be supplying their own money for the project and nothing else, no aid from any other person or corporation. If the car happens to go over budget, oh well, money is money after all, and school is just a learning experience where failure should happen. The overage will be noted in the final part of the construction section in this proposal.

8. DISCUSSION

a. Design

The design started with a few simple analyses to get started thinking about the layout of the differential. From there, three differential sketches were formed, one chosen for the one to be used in the RC. During the drawing of this differential cover, everything went as planned until it was discovered that there were not gears available that would be small enough and the right size to fit. This was not so much a pressing issue at the time since it was the beginning of the design. Next, analysis for the drive shafts was done with set parameters which applies to the pins that connect the differential to the driveshafts. This helped aid in the new design for the differential that needed to be reconstructed eventually. Leading from this, multiple torque analysis helped design the new differential covers shaft diameter. After this, a drawing of the internal pin for the differential gears spacing was constructed. In the beginning, a rounded end was drawn in to allow the pin to slide in the whole easily. This was problematic when it came to the assembly for the whole differential because SolidWorks would not let the two surfaces mate together since they were not both flat. This had to be corrected for the assembly to be complete, hence, the rounded ends were removed and 0.5mm was added to the length of the shaft as a result. Next, there are four internal gears that are identical in the differential and they were drawn next. Since the student version of SolidWorks does not have toolbox, the gear had to be drawn by hand using a gear profile. Although the gears are not being printed or manufactured, they were drawn for the sake of the assembly drawing and gear animation. After finding gears that would work inside a differential, the housing itself was reconstructed. This time, the differential has four main gears and then the two gears connecting to the drive shafts. A gear profile was added to the outside of the differential cover so it can be printed, avoiding the task of having to find a ring gear that fit the specific dimensions. The pins that were used inside the differential incidentally double as the pins for the wheel hub assembly as well. The pins job in the differential is to keep the gears in line as well as to space the gears out since the design of the internal gears is quite complex. One issue that occurred during the assembly was the extruded boss that spaced the gears out, so they did not touch other gears. Two of them were not extruded enough and this caused a couple gears to overlap, this was fixed by simply increasing the height of the differential top cover was made to enclose the gears. This was made to be watertight so that the grease added to the gears after construction does not get contaminated.

b. Construction

During the manufacturing process many issues came about but there was one aspect that was a factor for almost each component, this factor was support material. After the differential housing was printed assembly of the internal gears came next. What was discovered was not only were the holes slightly too snug for the pins to be press fit, but that after they were it made the material very weak and a couple pin housings sheared off. To solve this problem, material was added to each of the holes to make the outer radius 2.5mm while the inner radius was nearly half at 1.3mm. This will add strength to those just in case driving the car fully assembled causes any of this type of shear to happen. Although according to calculation the internal gears should be just fine once assembled. To ensure that the posts would be sturdy for the pins, fillets were added to the bottom of each to make them more resistant to the shear and bending forces they would experience from the constant torque from changing directions. The screw holes were also far too thin so to compensate for this the OD was changed to 5mm alike the other holes. The different is that the screw holes were already touching the side wall with the increased diameter, fillets were added to fill the excess space. A smaller fillet of 1.75mm radius was added to the wall betwixt the posts, and a larger fillet meant to almost fill the larger gap of 3mm radius was added. This will strengthen the holes and allow them to be piloted without shearing off prematurely. Originally the hole for the drive shaft was assumed to be 4.8mm in diameter for the drive shafts chosen, but the gear pack purchased came already with 4.8mm shafts so the diameter had to be increased to 5.0mm. The last revision accounts for the distance the ring gear occupies in between the top cover and the housing. This distance is 4mm and was not accounted for in the last design, so it did not fit with the transmission housing. Therefore, 7mm of length was removed from the housing. This shouldn't pose a problem for spacing since the spacing for everything will be the same as the ring gear shall be occupying it.

Nearing the assembling of the device, everything was fitting and working great until it was evident that the drive shafts were far too long and not the right shape. The drive shafts were then modified to be an entire inch shorter and bosses were added to the side where the suspension was going to be mounted. The bosses helped with supporting the suspension that were mounted on end to each a-arm. Also, bosses were added to the locations that the pins pierced through due to the first few prints giving iffy results when removing support material. Some of them would split at almost no force.

Control arms in the front ended up not being long enough and they interfered with the suspension so 3/8" dowls were put into place as a mounting point near the front of the car to move them out of the way but to still have them function properly.

c. Testing

Details of the testing process can be found in appendix G. Testing for the most part went smooth with the car performing successfully. There were some hiccups however, during the second trial of the temperature test the differential gear stripped from its plastic housing. This was fixed in mere minutes and the car was back up and running until the end of the third trial where the plastic completely stripped. This is a failure due to the type of plastic being used and the lack of infill that the 3D printer can do.

The first trial of the acceleration tests the car ended up colliding with one of the barriers bordering the track. This caused one of the a-arms to come free from the chassis which had to be fixed on the spot. This was repaired and further tests were able to be completed without any trouble. Other issues that occurred was the car getting a little unstable at high speed. Any small amount of input would cause the car to pull hard to one side or the other, this was not fixed.

9. CONCLUSION

For the entirely of the project, there are known tests the car must pass. These are a drop test, speed test, and off-road test. Yet these only happen if everything before it happens correctly such as the differential and chassis mounting points. So, besides the competition tests, the differential must perform general differential duties, the chassis must be able to house all mounting points for every component and the suspension must be able to withstand and break the fall enough so the chassis survives the fall. The differential, although not tested outside of SolidWorks, seems to be fully functional in the simulation it has been put through. Furthermore, it fits in the transmission housing which is even more of a reassuring factor. So, the differential will be able to successfully allow one wheel to spin at a different rpm than the opposing wheel. The chassis has been setup to be slightly larger than it need be and since it is being manufactured with wood, material can always be removed if needed. The extra material was added to ensure enough spacing between components and so there would be room for everything including the speed controller, batterie, steering servo, and receiver pack for example. This excess will prove to be enough room to fit each individual component as it was modeled in a separate partners assembly. The suspension towers implemented a higher safety factor adding a larger amount of material around the mounting points on the suspension tower to ensure it would not sheer. The extra material will prove to support the weight of the car and the shock setup will be just firm enough to break the fall of the car to reduce the stress inflicted on the chassis. With all these aspects being performed correctly and successfully the RC will run in tip top shape for the competition and for leisure driving as well.

10. ACKNOWLEDGEMENTS

During this project this RC Baja group received help from multiple people and other sources. Including: Dr. Choi, Professor Pringle, Jerols bookstore, CWU computer lab, the internet and the textbook “Mott”. The professors were very helpful with the analysis and in providing feedback on the various parts of the proposal. Each week they met with this team in order to answer any questions regarding analysis or drawings or simply what was required for a certain section. The bookstore recently signed a contract with Traxxas, so they are now selling their products which was ever so convenient for pricing out certain parts for the budget. The team was able to find an assembly blowup of all the parts included in a certain car to at least get an idea of how much the whole project was going to cost. The CWU computer lab provided access to SolidWorks for designing the components of the RC. Internet supplied multiple useful websites such as McMaster-Carr, MatWeb, and GrabCAD, all websites where prebuilt parts can be found and downloaded which made creating some parts easier. There were however no sponsors for funding or any other outside assistance.

References

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APPENDIX A - Analysis

Appendix A-1 – Pinion Gear Torque on Spur Gear

Analysis 1	MET 489A	Ryder Satall	Drawing 1

Pinion/spur gear Torque and Material:

Given: 1 kv = 1.341 hp   16t pinion gear, 90t spur gear.
3700kv motor   40,000 Rpm

Find: Torque on spur gear

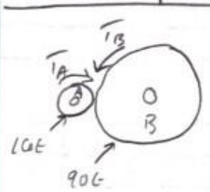
Assume: $\eta = 100\%$ massless   Scale = 1/10

Methods: Find rotational speed of gear B
Torque on gear B

Solution:

Pinion gear	Spur gear:
$\varnothing = 0.25$ in	$\varnothing = 1.5$ in
$16 = N_A$	$N_B = 90$

Rotational speed:



$$VR_{A-B} = \frac{n_A}{n_B} = \frac{N_B}{N_A} = \frac{90}{16} = 5.625$$

$$n_B = \frac{n_A}{VR_{A-B}} = \frac{40000\text{ rpm}}{5.625} = 7111.11\text{ rpm}$$

Torque:

$$T_B = \frac{P_{at\,B}}{n_B} = \frac{5095.8\text{ hp}}{7111.11\text{ rpm}} \qquad \frac{3800\text{kv}}{} \left| \frac{1.341\text{hp}}{1\text{kv}} \right. = 5095.8\text{hp}$$

$$= 0.7165 \left| \frac{33000\ \frac{\text{lb}\cdot\text{ft}}{\text{min}}}{1\text{ hp}} \right| \frac{1\text{ rev}}{2\pi\text{ rad}} \left| \frac{12\text{ in}}{1\text{ ft}} \right. = \boxed{45157.66\text{ lb}\cdot\text{in @ A-B}}$$

Perspective:

RC vs. Car

$$T_{car} = \frac{45157.66\text{ lb}\cdot\text{in}}{12} = \frac{3763.14\text{ lb}\cdot\text{ft}}{10} = 376.314\text{ lb}\cdot\text{ft}$$

Poisson's ratio:

A-36 = 0.32

Kevlar 49 = 0.34

Appendix A-2 – Differential Housing Material

Sheet SI-1	Analysis 02 - Differential cover	10/2/2020	Ryder Satau	1

Given: Adhesive, Plastic housing

Find: If any, what type of plastic, or carbon fiber, hold's best with what adhesive:

Assume: Gear has to be glued around differential housing in order to drive other gears within transmission.

Method: online research

Solution:

Plastics	Metals + Alloys	Adhesive
• ABS	• Aluminum	• Advanced epoxy
• Fiber Glass	• Copper	• Silicone
• Kevlar	• Zinc	• Cyanoacrylate
• Nylon	• steel	• UV Cure
• PEEK	• Brass	• JB weld
• Poly sulfone	• Bronze	• one part epoxy

Setup:

Plastic: Kevlar (if we can)
ABS (if kevlar not available)

Metal: Gear must be steel

Adhesive: One or two part epoxy

Parameters (°C):

Plastic: • ABS can withstand a range of $-20°C - 80°C$
• Kevlar: Does not melt, will decompose @ 450°C

Metal: steel - 870°C melting point

Adhesive: One part: Cures anywhere from 100-150°C

Two part: Cures in a range from 24-30°C

Results | options

	Low	High
ABS:	-20	80
Kev:	N/A	450
Steel:	N/A	870
onepart:	100	150
twopart:	24	30

ABS/steel/two part

Kevlar/steel/one part

Appendix A-3 – Differential Pin

Analysis 3	Met 487 A	Ryder Saton	1

Given: SAE 4130: Ultimate tensile strength 97 ksi

Find: Required dia of a pin.

Solution:

$$d = \sqrt{\frac{4T}{D(\pi)(\tau_0)}} \qquad T = \frac{P}{n} \qquad \tau_0 = \frac{F}{A_0}$$

from A-1

$$T = \frac{66{,}066\,(0.52\,Hp)}{1422.22\,rpm} = 24.37\ lb{\cdot}in$$

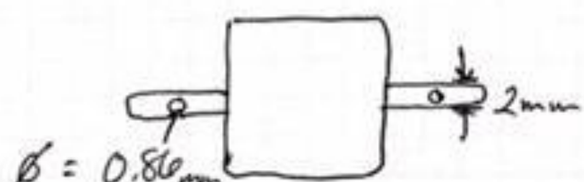
A-1

$$\tau = \frac{4T}{D\pi d^2} \Rightarrow d = \sqrt{\frac{4T}{D\pi\tau_s}} = \sqrt{\frac{4(24.37\,lb{\cdot}in)}{1.08\,in(\pi)(58\,ksi)}}$$

$= 0.017$ in min dia. ≈ 0.43 mm

F.S. Employed = 2. => Hole is now 0.86 mm dia.

However, shaft dia. will need to be 2mm rounded up for saftey.



Appendix A-4 – Batterie Output/RPM

Analysis 4 | | Ryder Satau

Given: - Batt. size: 7.4v 5200 mah Li-po.

Motor output: 100,000 RPM @ 11.1 v

Find: Motor output w/ batt. required

Solution:

$$\frac{100{,}000\,\text{RPM}}{11.1\text{v}} = \frac{x}{7.4\text{v}}$$

$$\rightarrow 100{,}000(7.4) = 11.1x$$

$$\rightarrow 11.1x = 740{,}000$$

$$\rightarrow \boxed{x = 66.666.67\,\text{RPM}}$$

Appendix A-5 – RPM Requirement

1/1

Ryder Satas | Analysis 5 – MET489A | 20201015 | 1

Given: Tire $\emptyset_{small}$: .10m Tire $\emptyset_{large}$: 0.12m

Car must reach a speed of 30 mph

Find: Wheel rpm for this to be possible

Assume: · Neglect torque on gears (gradual increase in speed)

· Assume gear ratio 1:1

Solution:

$$\frac{30\ mi}{1\ hr}\Big|\frac{1.609\ km}{1\ mi}\Big|\frac{1000\ m}{1\ km}\Big|\frac{1\ hr}{3600\ s} = 13.408$$

$$V_{car} = 13.41\ m/s \Rightarrow V = \omega r$$

Small dia:

$$r = 0.1m \Rightarrow \frac{13.41\ m/s}{0.10m} = \frac{\omega(0.10m)}{0.10m}$$

$$\omega = 134.08\ rad/s$$

$$\text{Output RPM} = \frac{134.08\ rad}{s}\Big|\frac{1\ rev}{2\pi\ rad}\Big|\frac{60\ sec}{1\ min} = \underline{1280.37\ RPM}$$

Large dia:

$$r = 0.12m \Rightarrow \frac{13.41\ m/s}{0.12m} = \frac{\omega(0.12m)}{0.12m}$$

$$\omega = 111.75\ rad/s$$

$$\text{Output RPM} = \frac{111.75\ rad}{s}\Big|\frac{1\ rev}{2\pi\ rad}\Big|\frac{60\ sec}{1\ min} = 1067.13\ RPM$$

The small wheels need to turn @ a rate of $\boxed{1280\ RPM}$

The large wheels need to turn @ a rate of $\boxed{1067.13\ RPM}$

* The motor turns plenty fast so the smaller wheels will most likely be used because they are denser & will trace better for more of the challenges during the competition.

Appendix A-6 – Batterie

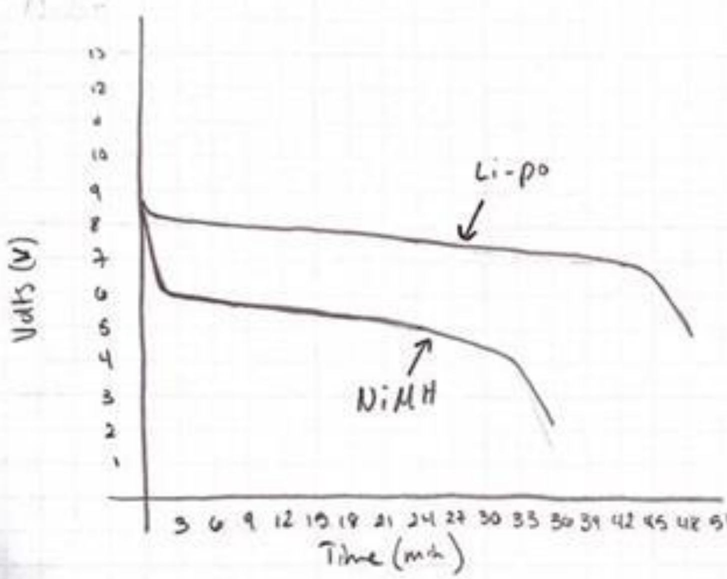
1/1 | Ryder Sotal | MET 489 - Analysis 6 | 20201015 | 1

NiMH vs. Lipo

Given: 7.4v lipo batt. 7 cell NiMH batt.

Find: Discharge curve

Solution:



* From the book as well as internet research, it was found that Li-po batteries are far superior to NiMH due to their discharge curve. The NiMH batt. gradually fall so you never get peak performance from them for more than a few minutes. Lipo's on the other hand hold their high voltage for longer giving the most power output for almost the full charge of the batt.

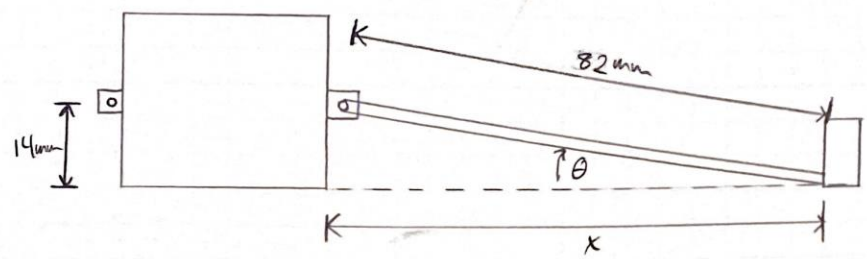
- A 2-cell 5400 Mah 50c Lipo batt. will be used in the baja to increase performance, drive time and consistency.

Appendix A-7 – Drive Shaft Angle

Given: · Drive shaft length
· Distance from mount to wheel hub (82 mm)
· Thickness of Transmission cover (2 mm)

Find: Angle of Drive Shaft: $\theta < 25°$

Solution:



$$dx = \sqrt{(l_{shaft})^2 - (h)^2}$$
$$= \sqrt{(82)^2 - (14)^2}$$
$$dx = 80.796\,mm$$

$$\theta = \tan^{-1}\left(\frac{y}{x}\right)$$
$$= \tan^{-1}\left(\frac{14}{80.796}\right)$$
$$\boxed{\theta = 9.83° < 25°} \checkmark$$

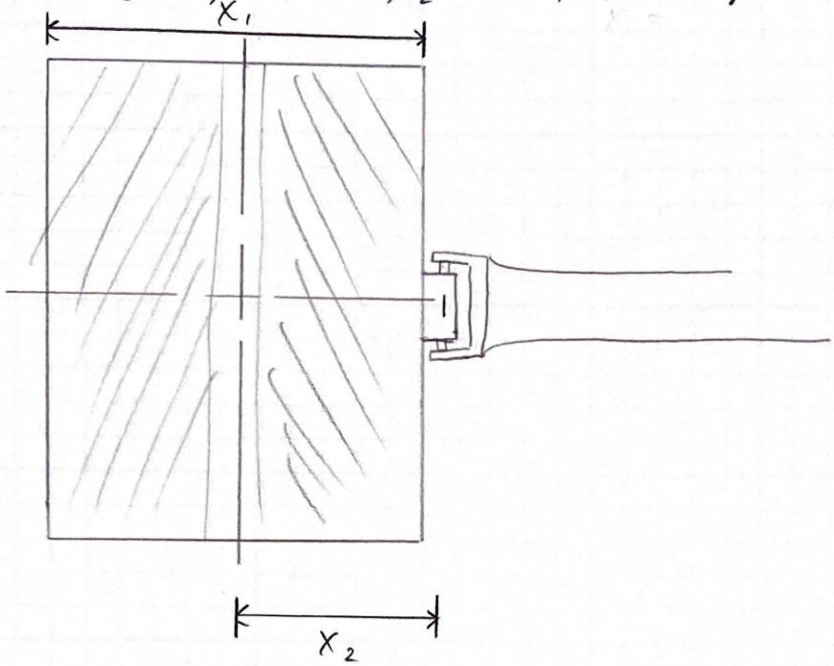
Appendix A-8 – Torque on Wheel

Ryder Sefan	Analysis 8	20201022

Given: weight, μ static friction, wheel width, distance from hub to drive shaft connection

Find: Torque required to spin wheel. $\tau \le (8\,kg/cm)$

Assume: $\mu_s = 0.7$, $X_1 = 90mm$, $X_2 = 25mm$, $W_1 = 4.45kg$



$$\tau = W\mu_s\sqrt{\frac{X_1}{8} + X_2^2}$$

$$= 4.45kg\,(0.7)\sqrt{\frac{(9.0cm)^2}{8} + (2.5cm)^2}$$

$$\boxed{\tau = 12.6\ kg/cm}$$

Appendix A-9 – Gear up RPM

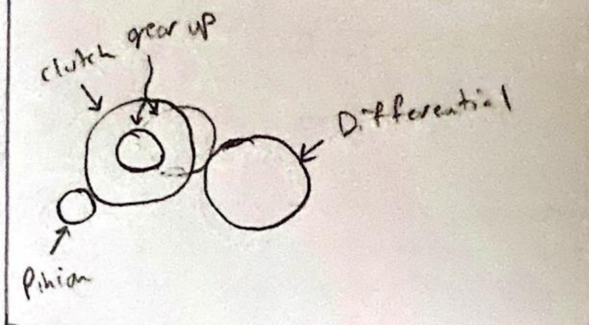
Analysis 9	20201029	Ryder Sutton

Given: Gear up, image drawn, [redacted]

Find: Pinion RPM needed for 30mph

Assume: Previous analysis are correct

Methods:



Soln:

Pinion: 16t

clutch: 91t

Gear up 1: 21t

Gear up 2: 31t

Diff: 60t

$r = 0.033\,m$

$$\frac{13.41\,m/s}{0.033} = \frac{\omega(0.033)}{0.033}$$

$$\omega = 406.36\ rad/s$$

$$\text{Output RPM} = \frac{406.36 \cdot 60}{2\pi}$$

$$= \underline{38298.87\,RPM}$$

Diff. Rpm

1st:

$VR = 60/31 = 1.935$

$\omega = 38298.87/1.935 = 19787\ rpm$

2nd:

$VR = 31/21 = 1.476$

$\omega = 19787.74/1.476 = 13404.6\ rpm$

3rd:

$VR = 21/91 = 0.231$

$\omega = 13404.604/0.231 = 58086.62$

4th:

$VR = 91/16 = 5.6875$

$\omega = 58086.62/5.6875 = 10213.03$

To reach 30 Mph the pinion gear will have to Spin @ $\boxed{10213.03\ Rpm}$

Appendix A-10 – Torque on

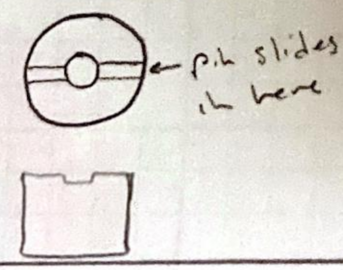
Analysis 10 | 20201029 | Ryder S[illegible]

Given: Rpm 13404.6

Finds: Torque on gear up pin

Assume: SAE 4130 tensile strength 97ksi

Methods:



Soln:

$$T = \frac{4\tau_s}{D\pi d^2} = \frac{4(97ksi)}{1.3cm\,\pi(2mm)} = \boxed{47.5\,lb\,in}$$

Appendix A-11 – Motor output Hp/ Pitch Line Speed

Analysis 11	Ryder Safar	20201105	1

Given:

Castle 3700 kv motor Max $\eta_{motor} = 0.94$, 11.6 amps, 7.4v

from castle creations.com average output with a max of 20A

Find: Motor output Hp average.
Pitch line speed

Soln:

HP:

$$HP = \eta I E / 746 \qquad 1\,Hp = 746W$$

$$= \frac{0.94 \cdot 11.6\,Amps \cdot 7.4v}{746W}$$

$$= 0.10816$$
$$\approx 0.11$$

$$\boxed{HP_{avg} = 0.11}$$

Pitch line speed:

$DP = 0.394"$
$n_p = 10213\,rpm$
$PWR = 0.11\,Hp$

Eq 9-1
Pg 321

$$V_t = \frac{\pi D_p n_p}{12} =$$

$$V_t = \frac{\pi(0.394" \cdot 10213\,RPM)}{12} =$$

$$V_t = 1052.93\,ft/min$$

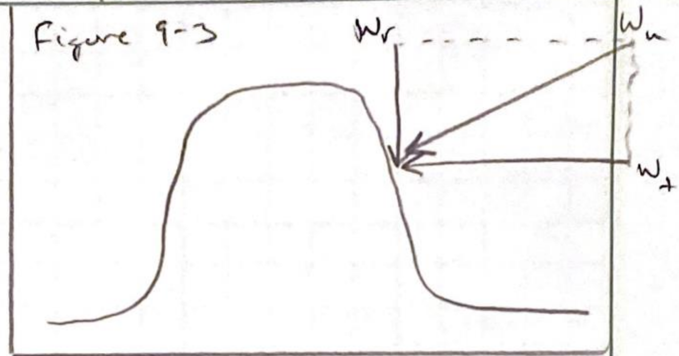
$$\boxed{V_t = 5.35\,m/s}$$

Appendix A-12 – Forces on Internal Differential Gears

Analysis 12 | Ryder Safak | 20201105

Given:
- Pressure angle: 20°
- Power: 0.11 Hp
- Pinion speed: 10,213 RPM
- Pitchline speed: 1052.93

Figure 9-3



Find: Tangential force
Radial force
Normal force

Soln:

Tangential force:

$$W_t = \frac{P}{V_t} = \frac{0.11\,Hp}{1052.93} \cdot \frac{550\ lbm\text{-}ft/s}{1\,Hp} \cdot \frac{60\ sec}{1\,min} = 3.45_{lbf}$$

$$\boxed{W_t = 3.45_{lbf}}$$

Radial force:

$$W_r = W_t \tan\theta$$

$$\Rightarrow W_r = 3.45_{lb}(\tan(20°)) = 1.26$$

$$\boxed{W_r = 1.26_{lbf}}$$

Normal force:

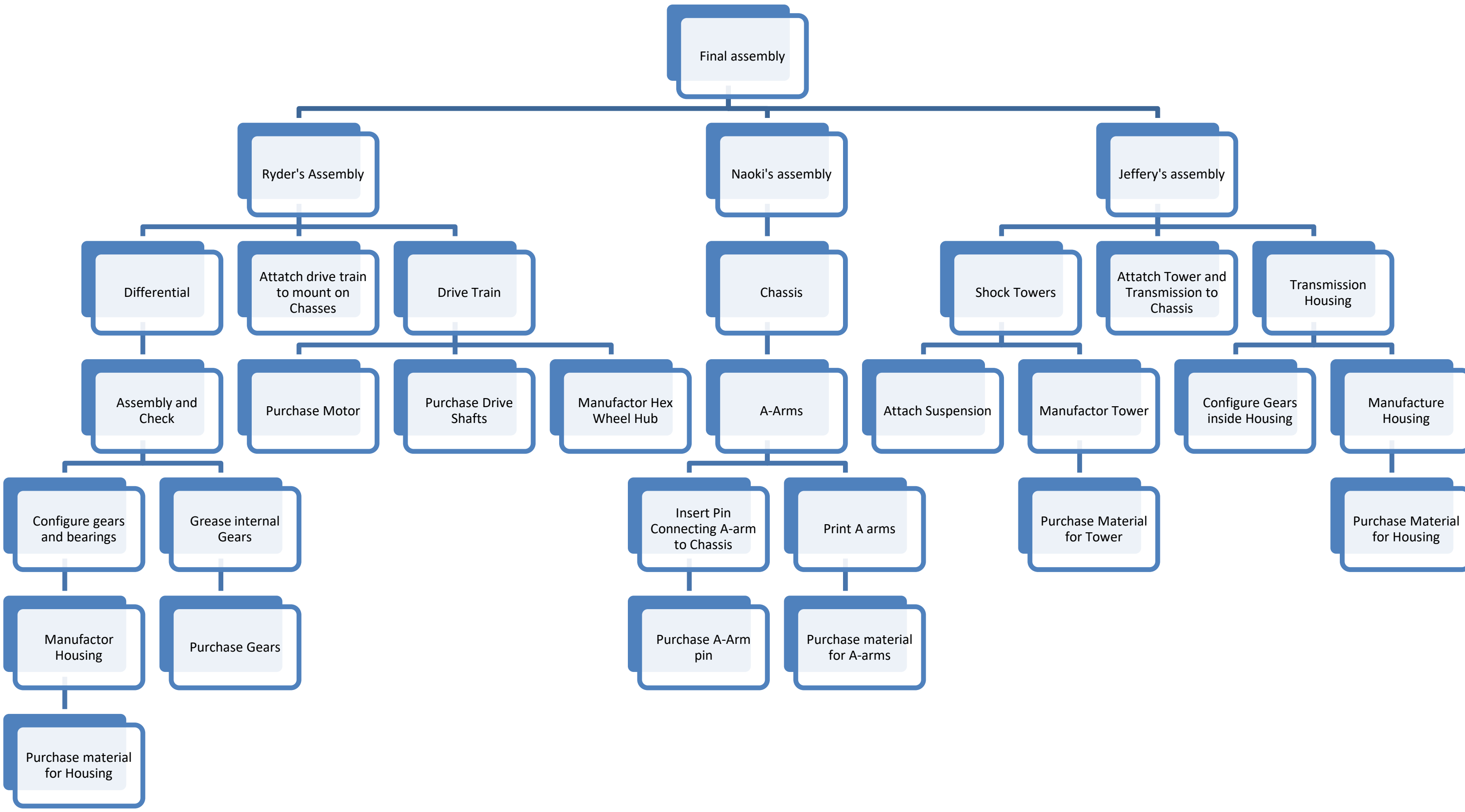
$$W_n = W_t / \cos\phi$$

$$W_n = \frac{3.45\ lbf}{\cos 20°} = 3.67$$

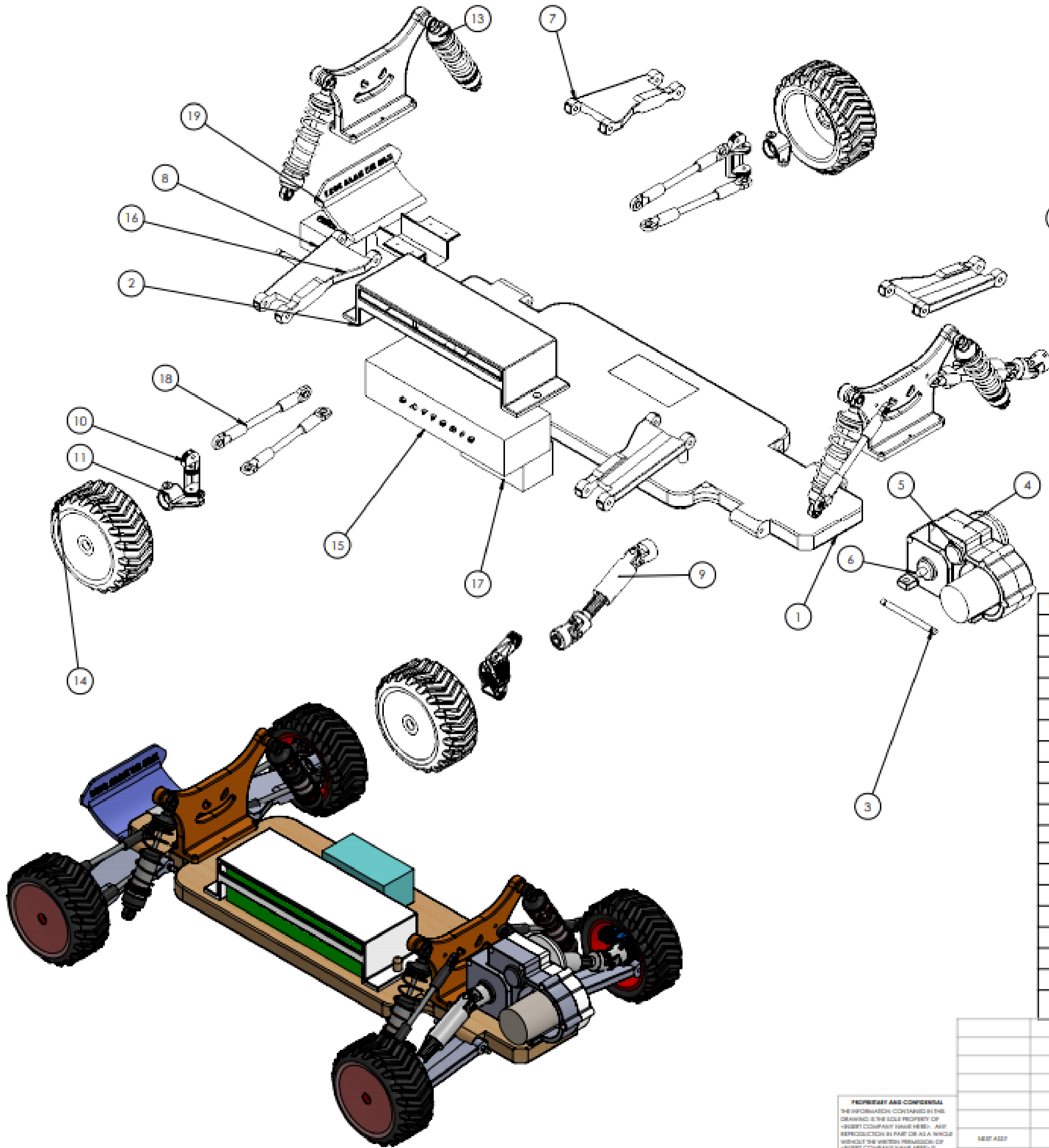
$$\boxed{W_n = 3.67_{lbf}}$$

APPENDIX B – Drawings

Appendix B – Drawing Tree



Appendix B – Complete Assembly



ITEM NO.	Description	Part Number	QTY.
1	Chassis Assmbley	10-002	1
2	Battery_Holder_V.2	20-004	1
3	A-arm_Pin	20-003	4
4	Transmission Assembly	10-003	1
5	Bearing	55-017	12
6	Diff.Ass.Q2	10-004	1
7	RightRearA-arm	20-002RR	2
8	LeftRearA-arm	20-003LR	2
9	Drive Shaft	55-032	2
10	Castor Blocks	55-026	1
11	Steering_block	55-027	2
12	Stub_axle_carrier	55-028	2
13	Suspension Assmebly	10-005/10-006	1
14	RCWheel and Tire	55-011	4
15	batterie	55-002	1
16	SERVO	55-004	1
17	SPEED CONTROL	55-001	1
18	Toe Link	55-021	4
19	Servo Cover and Bumper	20-012	1

RYDER SATAK

TITLE: RCBAJAASSQ2

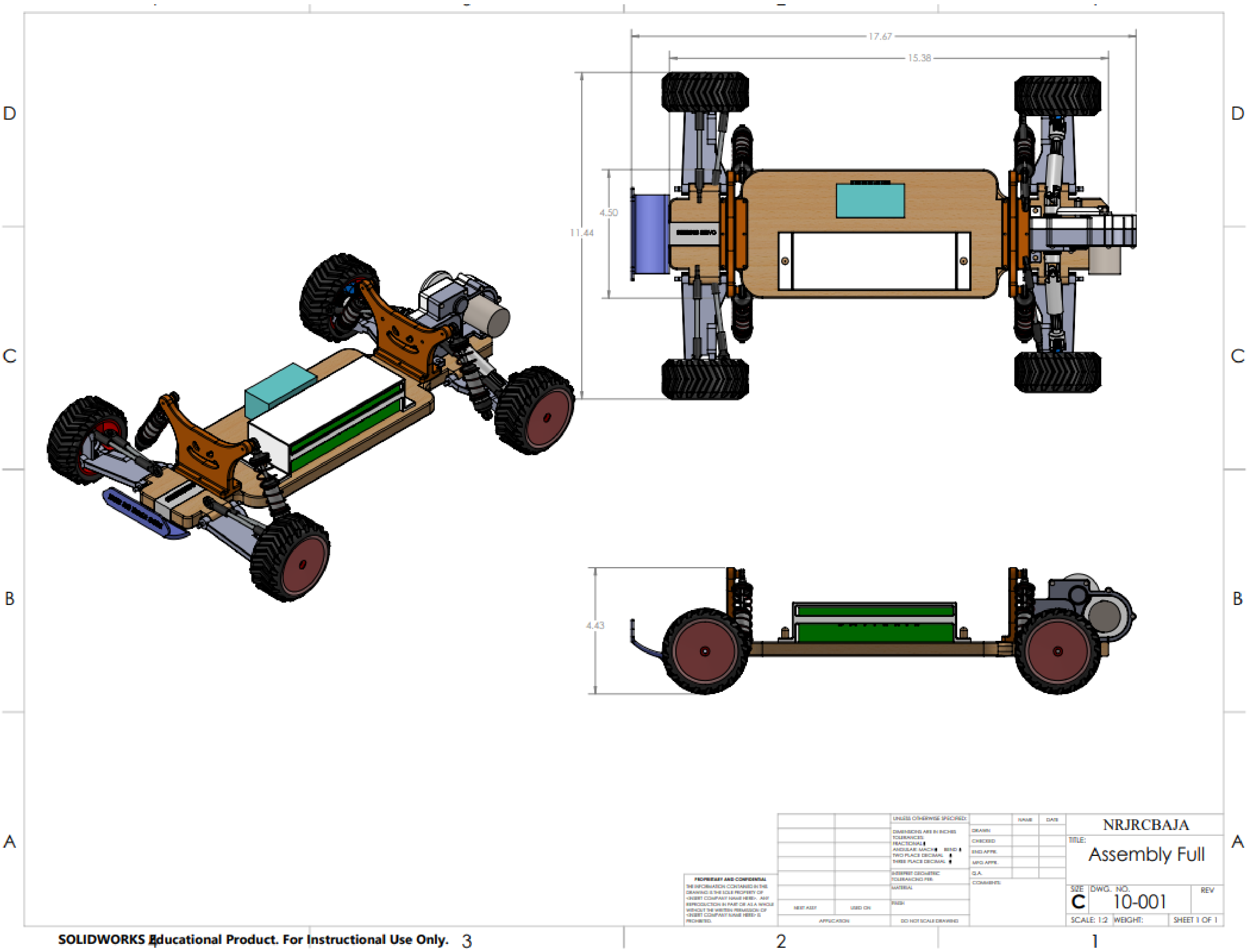
MATERIAL: PLA

FINISH: N/A

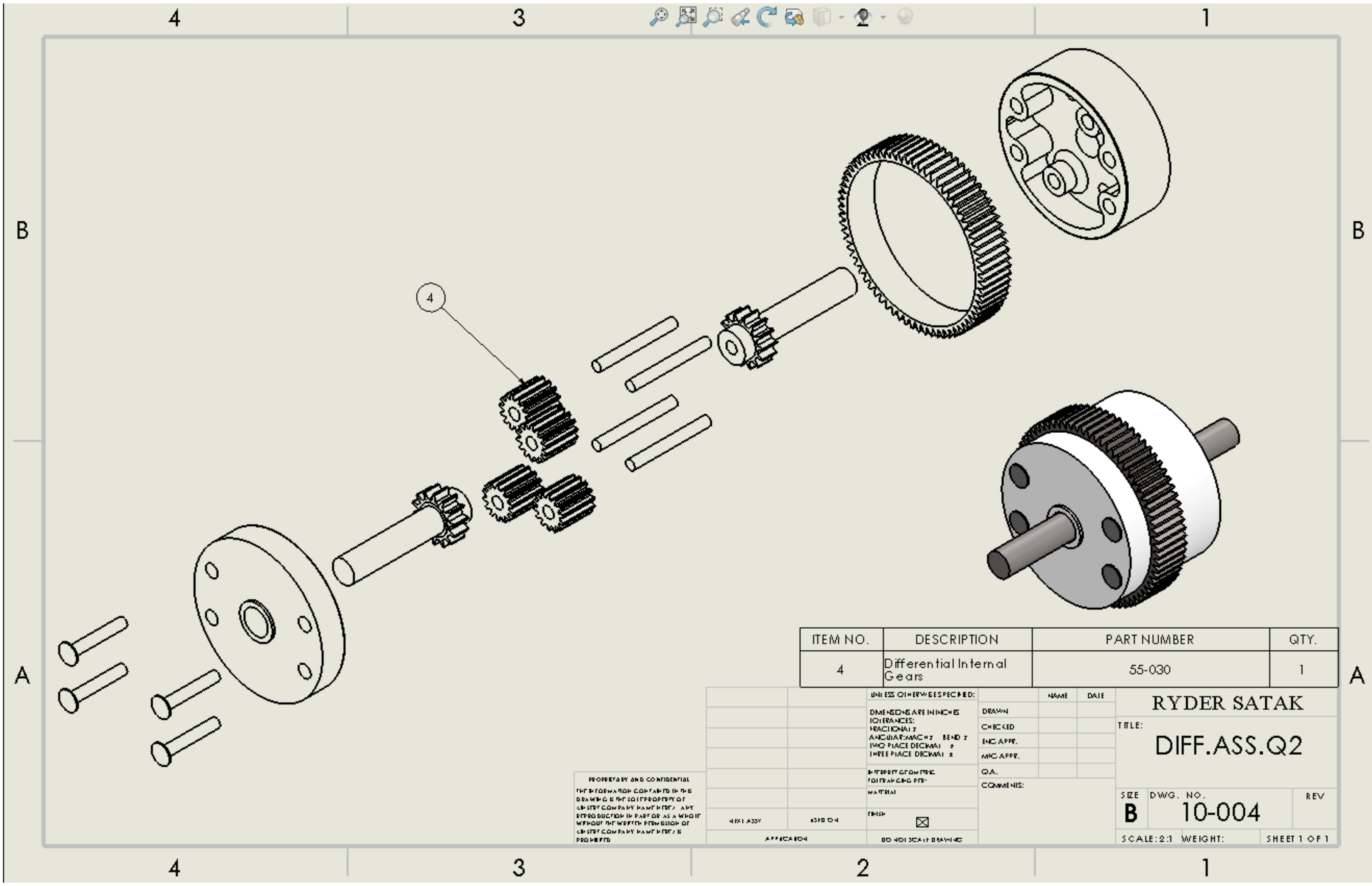
SIZE C | DWG. NO. 10-001 | REV

SCALE: 1:5 | WEIGHT: 5.0LBS | SHEET 1 OF 1

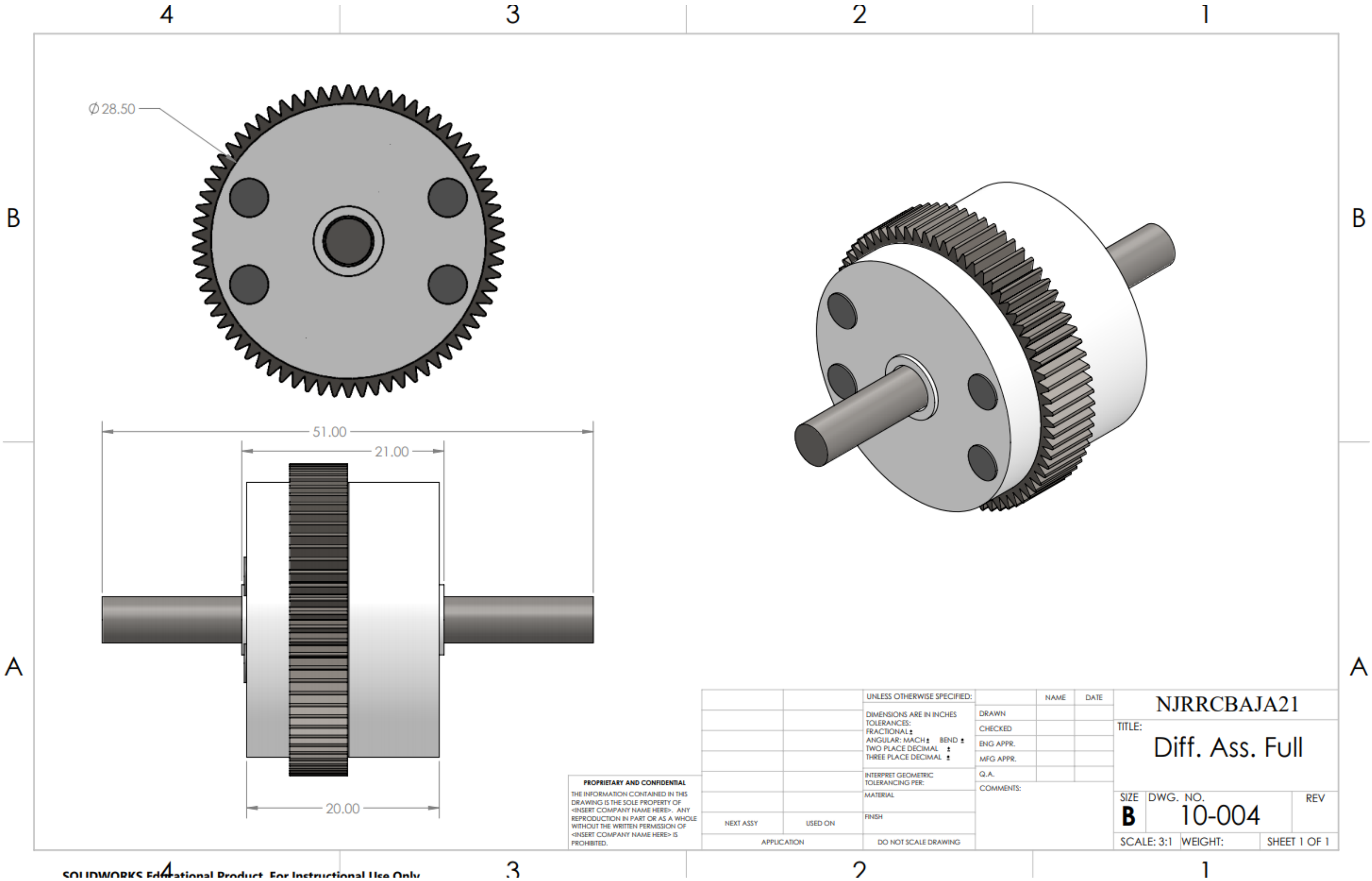
Appendix B – Complete Assembly Color



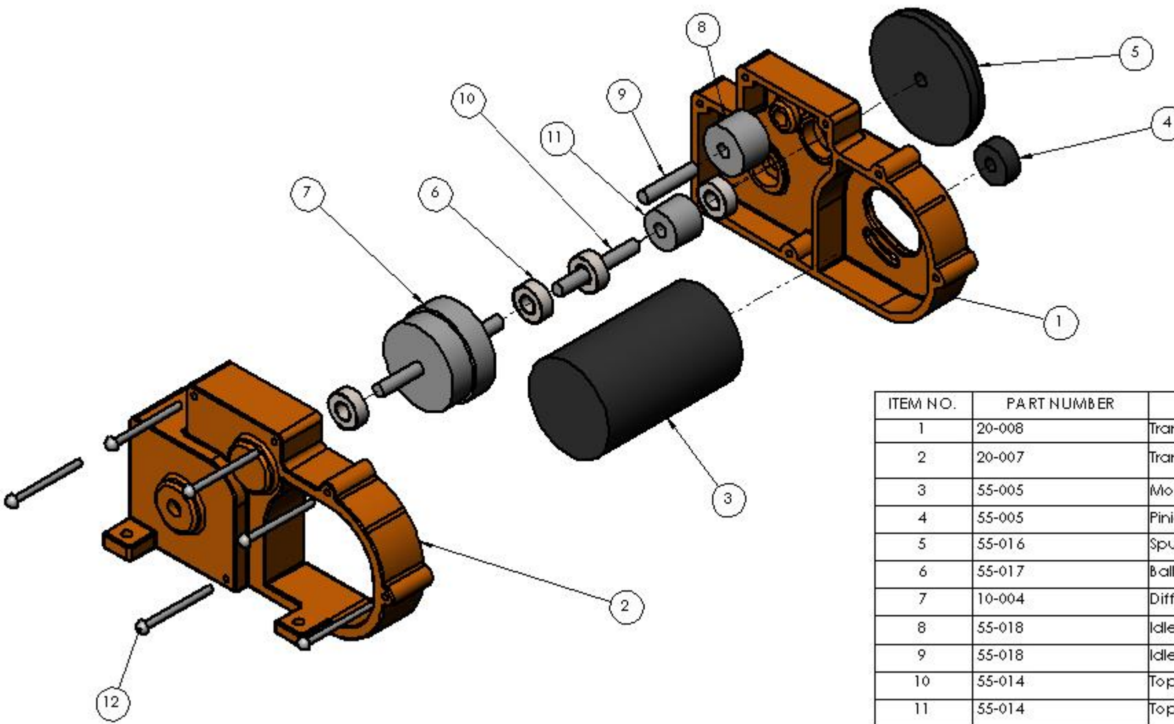
Appendix B – Differential Assembly



Appendix B – Differential Complete



Appendix B – Transmission Assembly



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20-008	Transmission Cover Motor Mount	1
2	20-007	Transmission Cover Motor Through	1
3	55-005	Motor	1
4	55-005	Pinion Gear	1
5	55-016	Spur Gear Slipper Clutch	1
6	55-017	Ball Bearing 5X11X4	4
7	10-004	Differential Assembly	1
8	55-018	Idler Gear	1
9	55-018	Idler Gear Shaft	1
10	55-014	Top Drive Gear Shaft	1
11	55-014	Top Drive Gear Shaft	1
12	50-001	M3x25 Screw	6

NRJ RC BAJA - HARN

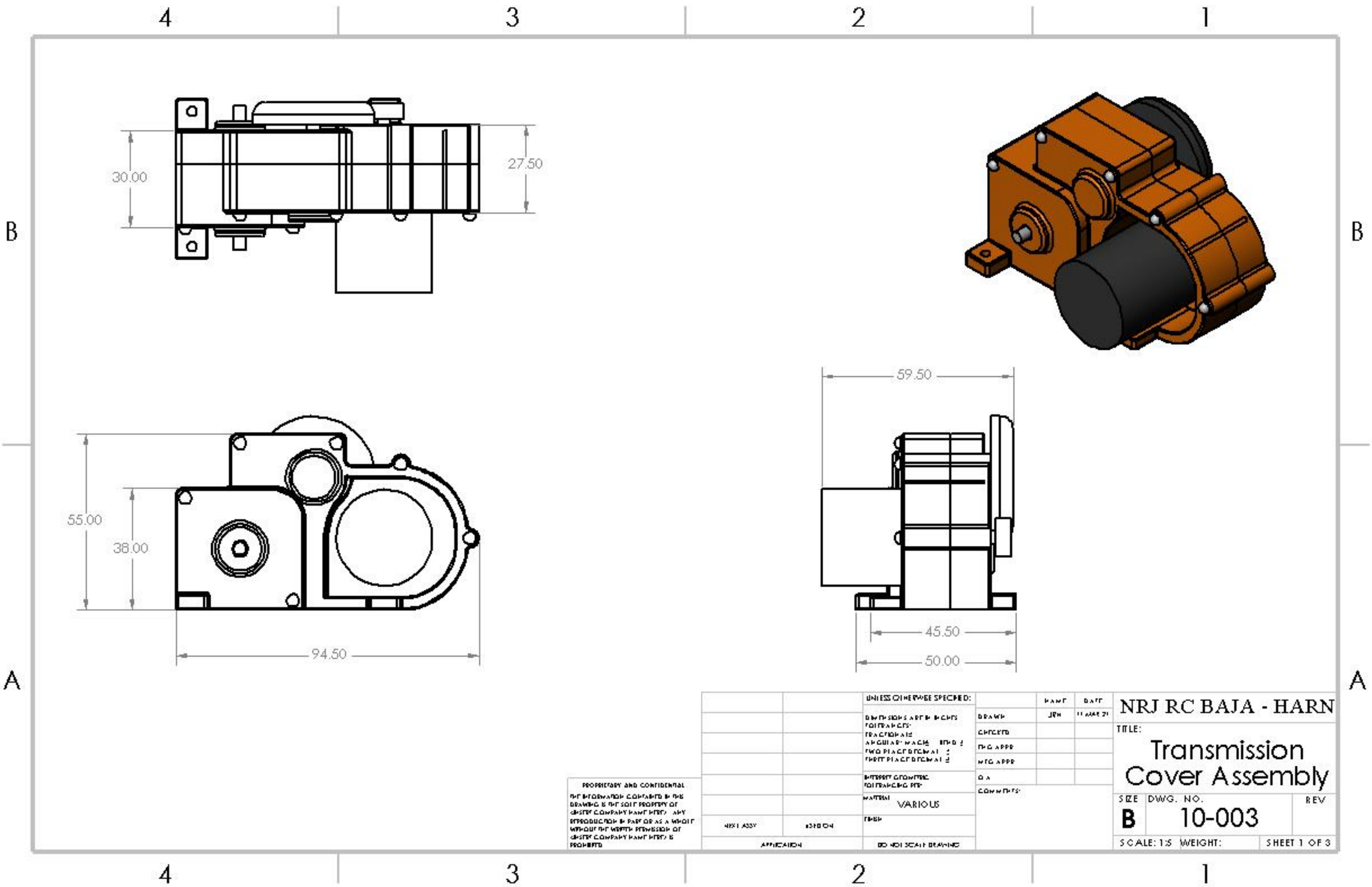
TITLE: Transmission Cover Assembly

MATERIAL VARIOUS

SIZE B DWG. NO. 10-003 REV

SCALE: 1:5 WEIGHT: SHEET 2 OF 3

Appendix B – Transmission

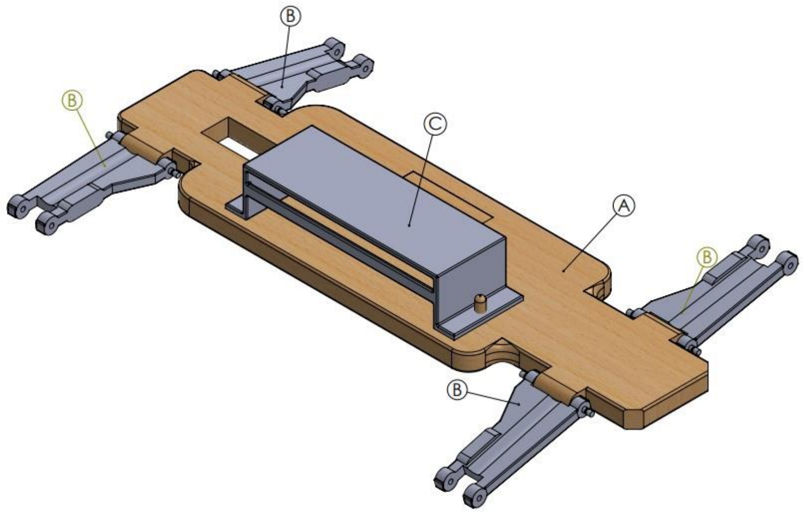


Appendix B – Chassis Assembly

4 3 2 1

REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED
B3	A	20-001 IS REV. 2	3/11/2021	
A3, B3, B4	B	20-002 IS REV. 2	3/11/2021	
B3	C	20-004 IS REV. 2	3/11/2021	

B



B

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20-001	Chassis	1
2	20-002LR	Left Rear A-arm	1
3	20-002RR	Right Rear A-arm	1
4	20-002LF	Left Front A-arm	1
5	20-002RF	Right Front A-arm	1
6	20-003	A-arm Pins	4
7	20-004	Battery Housing	1

A A

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

Naoki Masuda

TITLE: Assembly Complete

SIZE B DWG. NO. 10-002 REV 1

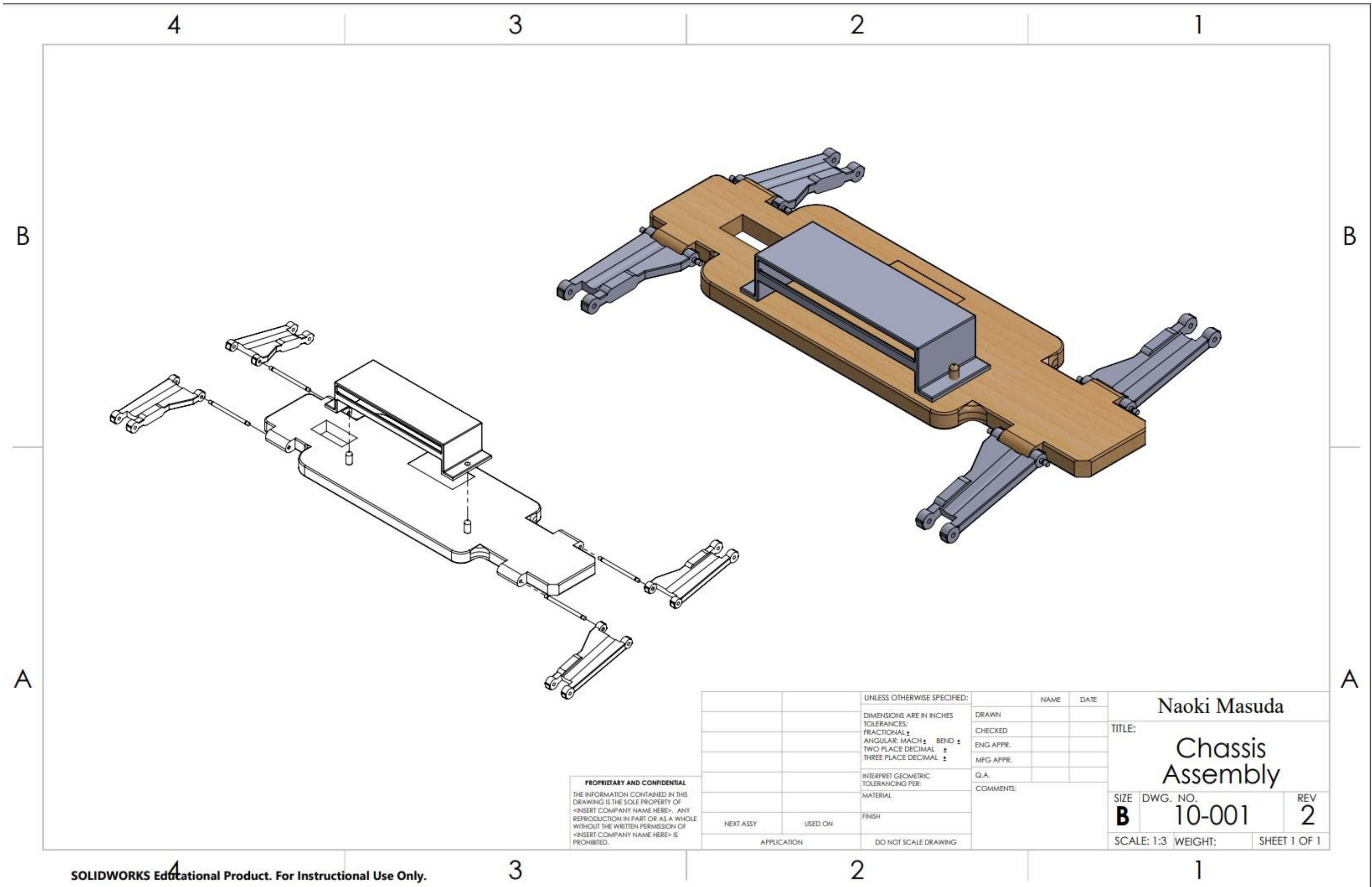
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

NEXT ASSY USED ON
APPLICATION

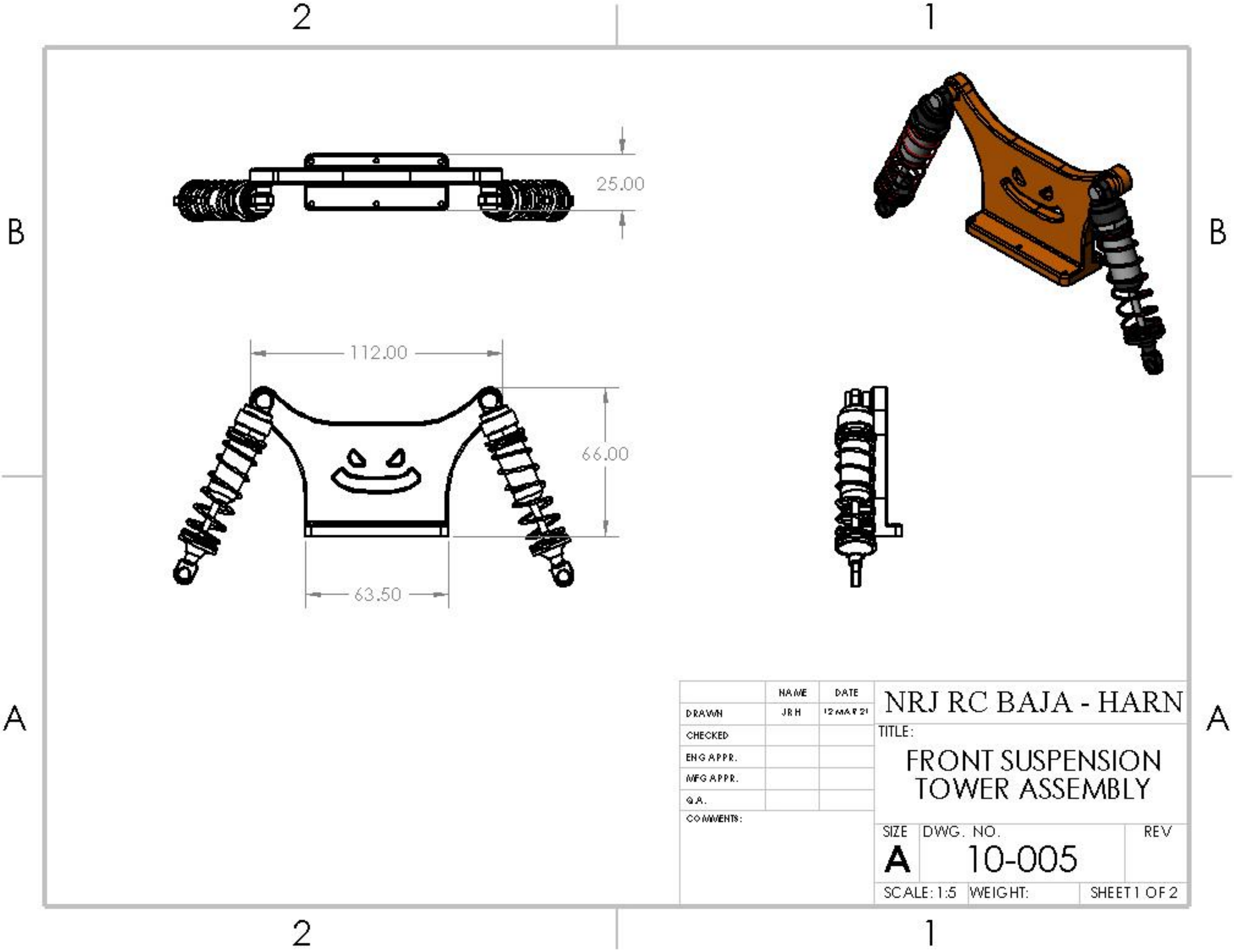
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

4 3 2 1

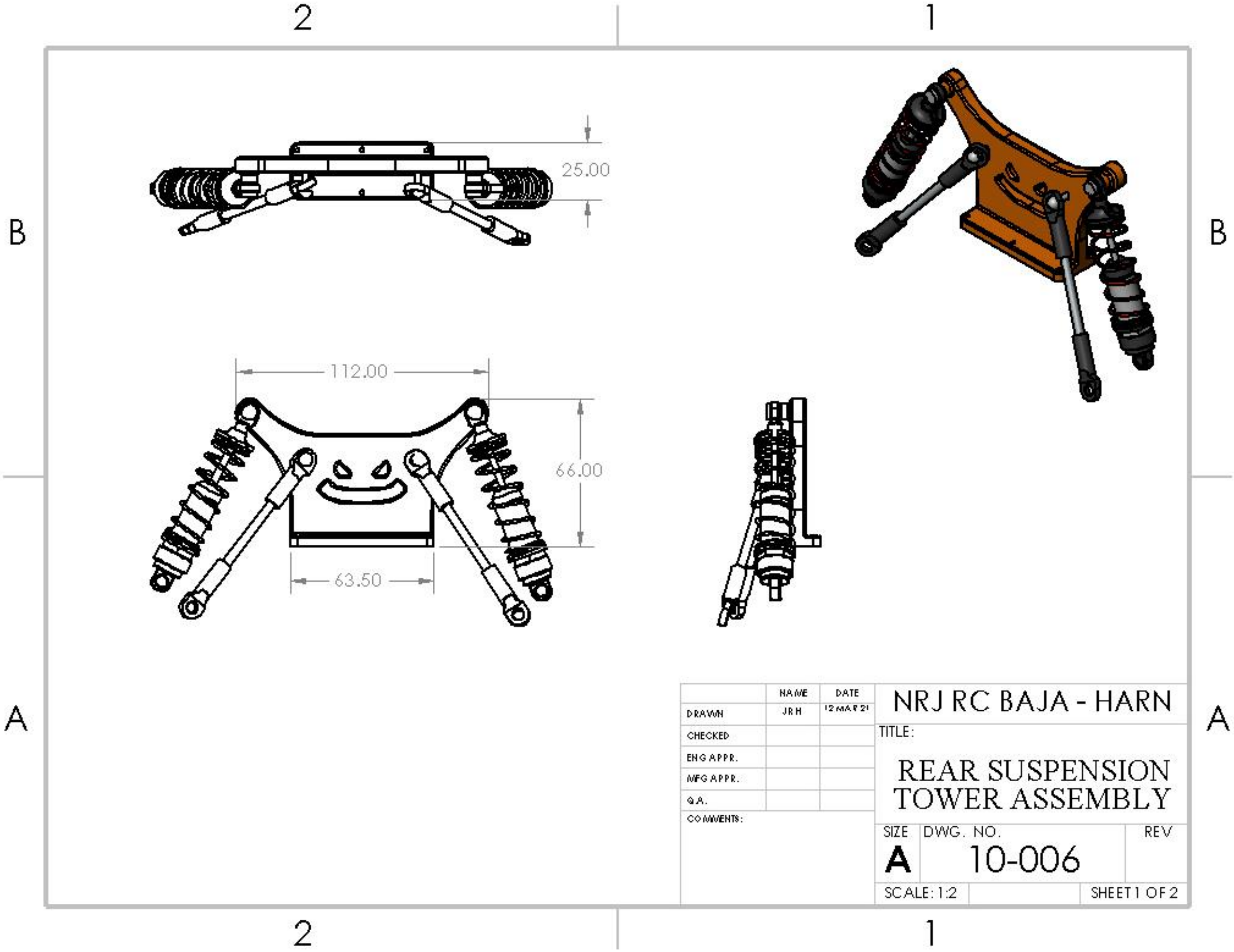
Appendix B – Chassis Assembly 2



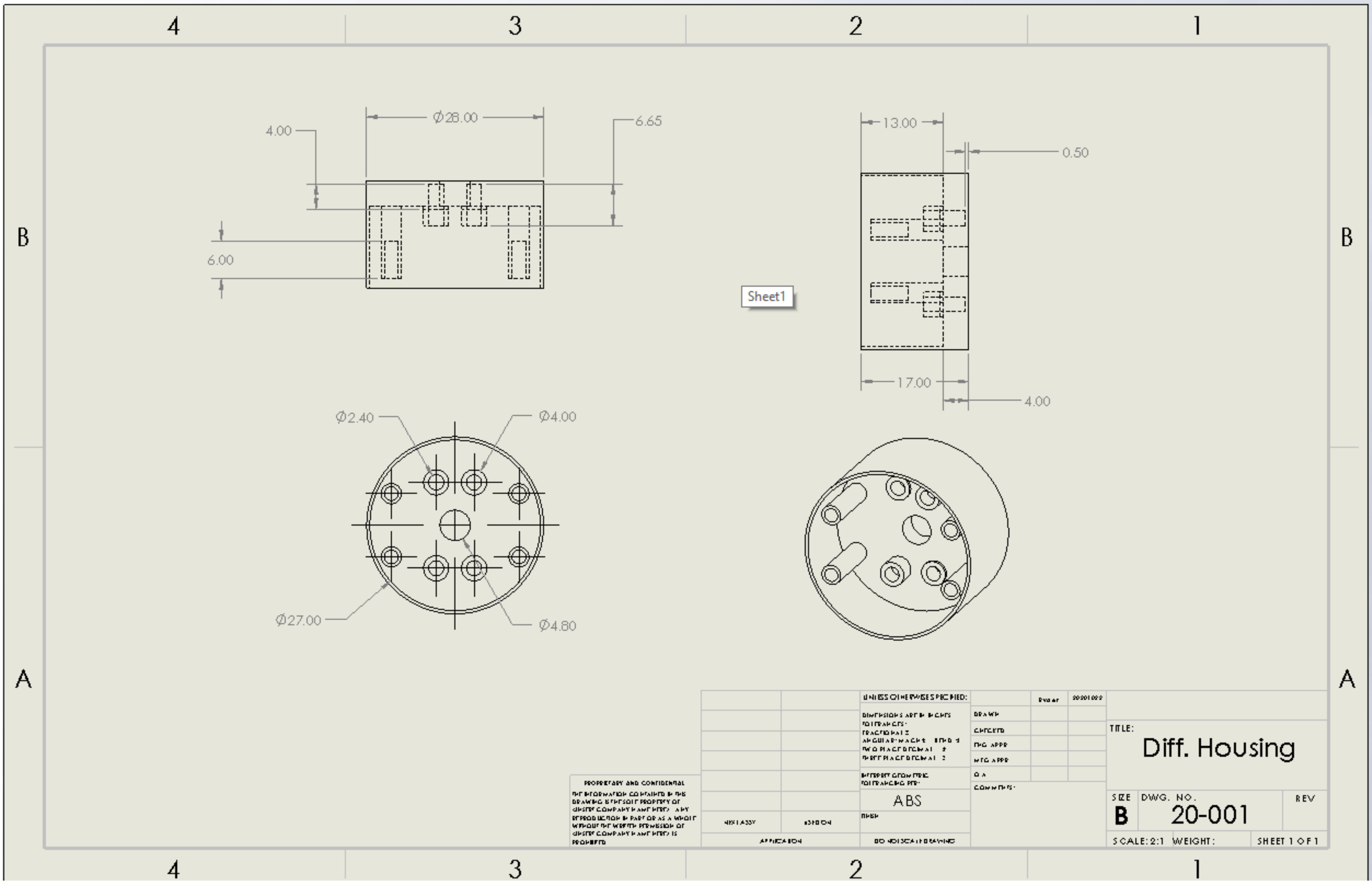
Appendix B – From Suspension Assembly



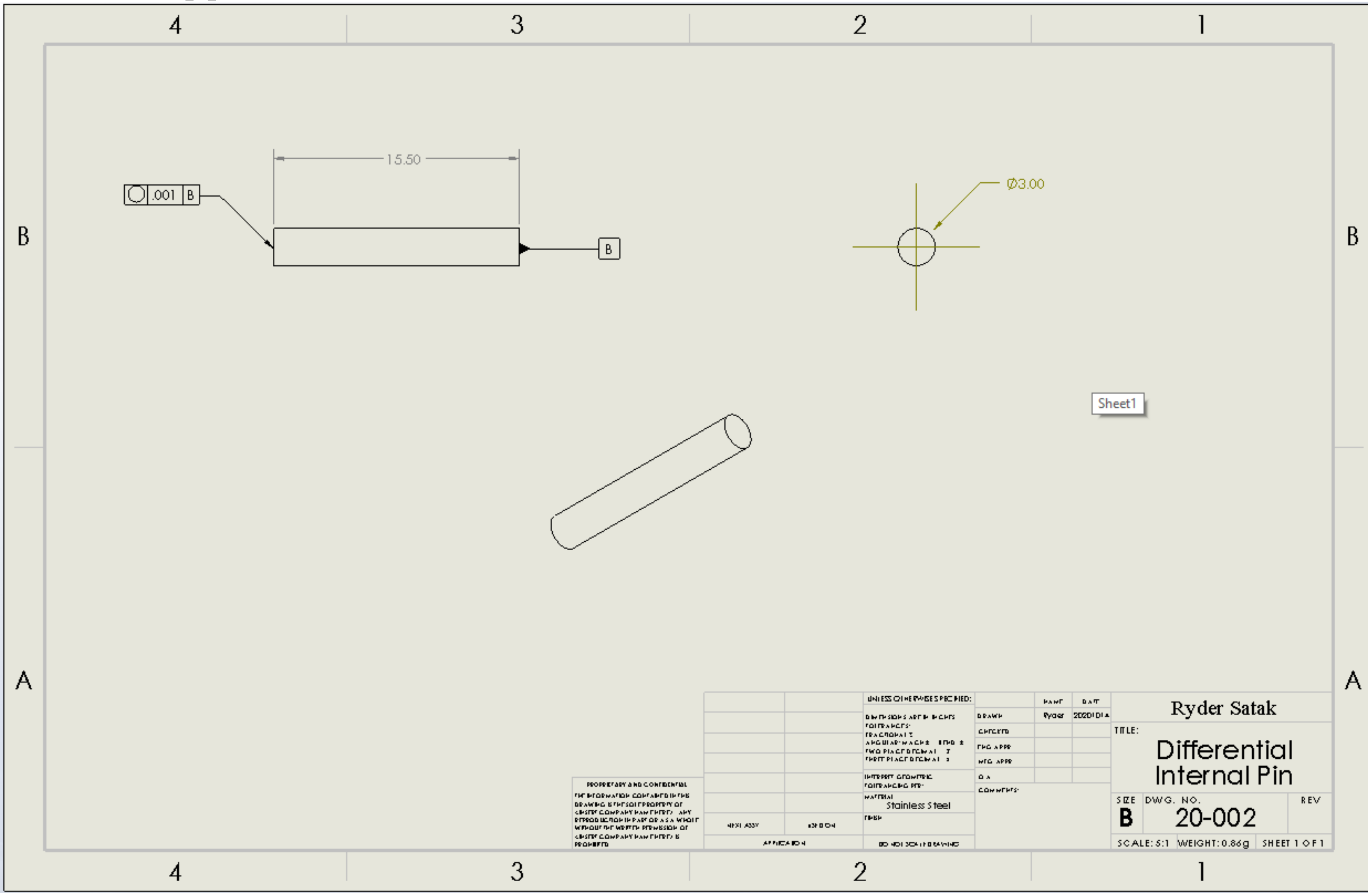
Appendix B – Rear Suspension Assembly



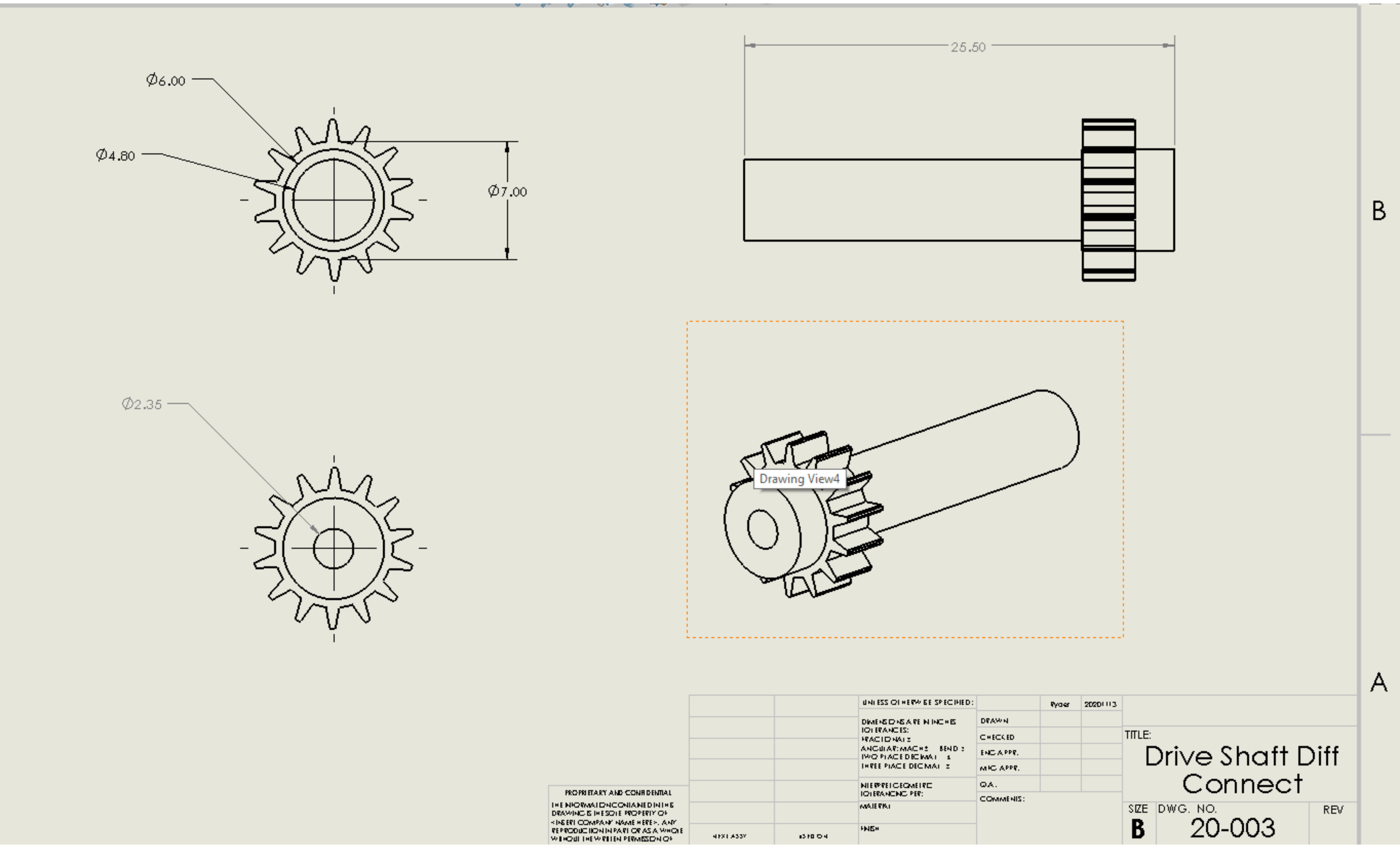
Appendix B – Differential Housing



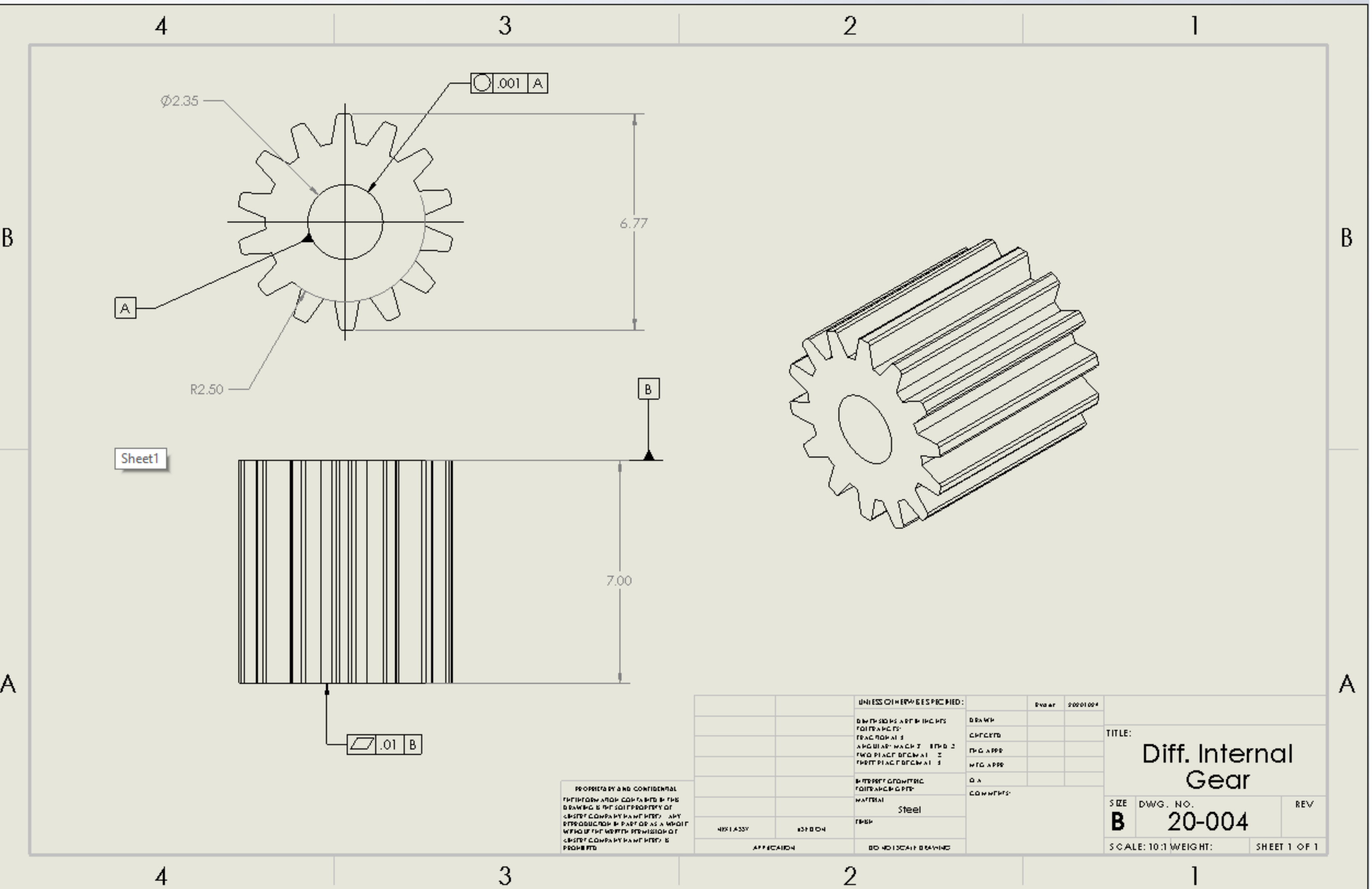
Appendix B – Drive Shaft Pin



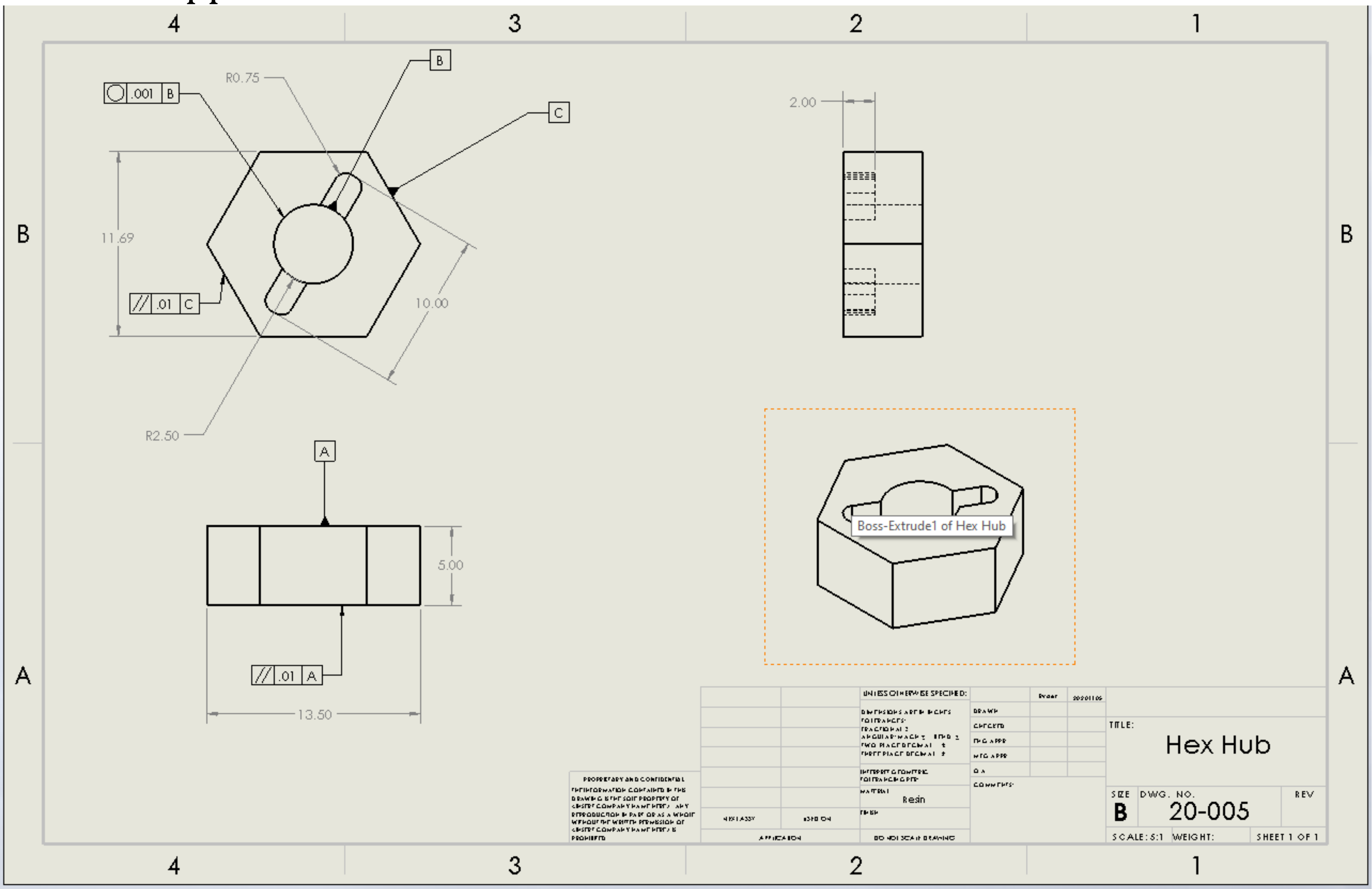
Appendix B – Drive Shaft Gear to Differential



Appendix B – Internal Differential Gear



Appendix B – Hex Hub



APPENDIX C – Parts List and Costs

1	Part Number	Qty	Part Description	Source	Cost	Disposition
2	10-001	1	Complete RC Assembly	Mfg	TBD	Team
3	10-002	1	Chassis Assembly (Chassis, A-arms, dowels)	Mfg	--	Masuda
4	10-003	1	Transmission Cover Assembly	Mfg	--	Harn
5	10-004	1	Differential Assembly	Mfg	--	Satak
6	10-005	1	Front Suspension Tower Assembly	Mfg	--	Harn
7	10-006	1	Rear Suspension Tower Assembly	Mfg	--	Harn
8	20-001	1	RC Chassis	Mfg	--	Masuda
9	20-002LR	1	Left Rear A-Arm	Mfg	--	Masuda
10	20-002RR	1	Right Rear A-Arm	Mfg	--	Masuda
11	20-002LF	1	Left Front A-Arm	Mfg	--	Masuda
12	20-002RF	1	Right Front A-Arm	Mfg	--	Masuda
13	20-003	4	A-Arm Pin	Mfg	--	Masuda
14	20-004	1	Battery Cover	Mfg	--	Satak, Masuda
15	20-005	2	Control Arm Dowel	Mfg	--	Satak, Harn
16	20-006	1	Front Suspension Tower	Mfg	--	Harn
17	20-007	1	Rear Suspension Tower	Mfg	--	Harn
18	20-008	1	Transmission Cover - Motor Mount	Mfg	--	Harn
19	20-009	1	Transmission Cover - Motor Through	Mfg	--	Harn
20	20-010	1	Differential Housing	Mfg	--	Satak
21	20-011	1	Differential Top Cover	Mfg	--	Satak
22	20-012	1	Front Bumper	Mfg	--	Satak
23	20-013	1	Rear Bumper	Mfg	--	Satak
24	20-014	1	Body Cover	Mfg	--	Harn
25	50-001	16	M3X25 Fastener Screw	Ace Hardware	0.33	Purchased 24 FEB 21
26	50-002	32	Washer 3mm	Ace Hardware	0.17	Purchased 24 FEB 22
27	50-003	16	M3 Nut	Ace Hardware	0.18	Purchased 24 FEB 23
28	50-004	4	Suspension Strut Fastener	Previously Owned	--	Satak Donation
29	55-001	1	Speed Controller	TBD	TBD	Purchased 17 FEB 21
30	55-002	1	Battery	Previously Owned	--	Satak Donation
31	55-003	1	Receiver Pack	TBD	TBD	Purchased 17 FEB 21
32	55-004	1	Steering Servo	Previously Owned	--	Harn Donation
33	55-005	1	Motor	Previously Owned	--	Satak Donation
34	55-006	4	Suspension Strut	Previously Owned	--	Satak Donation
35	55-007	2	Steering Block	Previously Owned	--	Satak Donation
36	55-008	4	Camber Block Front/Rear	Previously Owned	--	Satak Donation
37	55-009	1	Clutch Assembly	Previously Owned	--	Satak Donation
38	55-010	1	Gear-Up Assembly	Previously Owned	--	Satak Donation
39	55-011	4	Wheels	Previously Owned	--	Satak Donation
40	55-012	1	Battery Connector	Jerrols	TBD	Purchased 2 MAR 21
41	55-013	1	Shaft Slipper Clutch Roll Pin	Jerrols	3.00	Purchased 2 FEB 21
42	55-014	1	Top Drive Gear Steel 22-Tooth	Jerrols	3.00	Purchased 2 FEB 22
43	55-015	1	Slipper Pressure Plate Aluminum	Jerrols	8.00	Purchased 2 FEB 23
44	55-016	1	Spur Gear 86-T 48-P Slipper Clutch	Jerrols	3.00	Purchased 2 FEB 24
45	55-017	12	Ball Bearing 5X11X4	Jerrols	3.50	Purchased 2 FEB 25
46	55-018	1	Idler Gear 30-Tooth Steel	Jerrols	3.00	Purchased 2 FEB 26
47	55-019	2	Camber Links 49mm Rear	Jerrols	7.50	Purchased 2 FEB 27
48	55-020	4	Toe Links 59mm	Jerrols	8.75	Purchased 2 FEB 28
49	55-021	4	Toe Links 61mm	Jerrols	8.50	Purchased 2 MAR 21
50	55-022	2	Hex Hubs and Axle Pins	Jerrols	3.00	Purchased 2 FEB 28
51	55-023	2	Wheel Hub Hex	Jerrols	3.00	Purchased 2 FEB 29
52	55-024	2	Suspension Pins 44mm	Jerrols	2.50	Purchased 2 FEB 30
53	55-025	1	Screw Pin Set Suspension	Jerrols	4.50	Purchased 2 FEB 31
54	55-026	2	Caster Block	Jerrols	4.00	Purchased 2 FEB 32
55	55-027	2	Steering Block	Jerrols	3.00	Purchased 2 FEB 33
56	55-028	2	Stub Axle Carrier	Jerrols	3.00	Purchased 2 FEB 34
57	55-029	2	Front Axle	Jerrols	3.00	Purchased 2 FEB 35
58	55-030	1	Differential Gears	RC Hobbies Lacey	38.23	Purchased 20 JAN 21
59	55-031	2	Differential Ring Gear	Ebay	31.52	Purchased 11 JAN 21
60	55-032	1	Drive Shaft	RC Hobbies Lacey	8.59	Purchased 20 JAN 21

APPENDIX D – Budget

Item	Qty	Description	Cost
Motor	1	Castle 5700KV Sensored 1406	$60
Steering Arms	1	Traxxas Part # 3745	$8.75
Drive Shaft	1	Traxxas Part # 1951, 4628R	$10
Hub Hex	1	Traxxas Part # 3654, 1654(Rear)	$6
Hub Axel Pin	1	Traxxas Part # 2754	$1
Differential Gears	1	Traxxas Part # 2382	$6
Rear/Front Camber Arms	2	Traxxas Part # 3644	$7
Front Axel	1	Traxxas Part # 3637	$3
Front Steering Blocks	1	Traxxas Part # 3736	$3
Bearings	7	Traxxas Part # 5116	$3.50
Internal Gear Up	1	Traxxas Part # 3696, 3195, 3793	$9
Clutch Assembly	1	Traxxas Part # 4686, 5556, 5552X	$21
Axel Pin to Chassis	1	Traxxas Part # 2640	$2.50
Soldering Batterie	1	Service	$20.60
Receiver Pack	1	Spectrum Part # SR215	$30
Total	N/A	Budget Total	$165.70

APPENDIX E – Schedule

2																								
3	PROJECT TITLE: R/C BAJA 3																							
4	Principal Investigator: RYDER SATAK																							
5			Duration																					
6	TASK:	Description	Est.	Actua	%Comp	Septemb				October				November				Dec	January	February	March	April	May	June
7	ID		(hrs)	(hrs)																				
8																								
9	1	Proposal*																						
10	1a	Description	0.5	0.3		X																		
11	1b	Motivation	0.5	0.5		X																		
12	1c	Function Statement	1	1.5			X																	
13	1d	Requirements	0.75	0.5			X																	
14	1e	Engineering Merit	0.5	0.65				X	X															
15	1f	Scope of Effort	0.5	0.2				X																
16	1g	Success Criteria	1	1			X	X																
17	2a	Approach	0.5	0.5			X																	
18	2b	Design Description	3	4			X	X																
19	2c	Benchmark	0.5	0.5				X																
20	2d	Performance Predictions	0.5	0.5				X																
21	2e	Description of Analysis	0.5	0.75				X	X															
22	2f	Scope of Testing	0.5	0.15					X	X														
23	2g	Analysis	1	2.5						X														
29	3a	Methods	1.5	3						X														
30	3b	Construction	2	4							X													
31	4a	Introduction	0.5	0.5								X	X											
32	4b	Method/Approach/Procedu	1	2.25								X												
33	4c	Deliverables	0.5	0.15									X											
34	5a	Parts	0.5	0.15									X											
35	5b	Outsourcing	0.5	0.15									X											
36	5c	Labor	0.15	0.15									X											
37	5d	Estimated Total Cost	0.5	0.5									X											
38	5e	Funding Source	0.15	0.15									X											
39	6a	Design	0.5	0.5										X										
46	8a	Design	1	1										X										
51		subtotal:	20.05	26.1		Nov. 16																		
52						Septemb				October				November				Dec	January	February	March	April	May	June
53	1	Analyses																						
54	a-1	Pinion Gear Anal	3	3.75						X														
55	a-2	Differential Housing Mat.	0.5	0.75						X	X													
56	a-3	Differential Pin	1	1.25							X													
57	a-4	Batterie output/RPM	1	0.5							X													
58	a-5	Wheel RPM for Target Spe	1.5	2						X	X													
59	a-6	Batterie Discharge Curve	1	0.75						X														
60	a-7	Drive Shaft Length	0.75	0.5						X														
61	a-8	Torque on Wheel Hub	0.75	0.5								X												
62	a-9	Gear Up	1.5	2								X												
63	a-10	Torque on Gear Up Pin	1	1.5								X	X											
64	a-11	Motor output/Pitch line spe	0.75	1										X										
65	a-12	Forces on Gear Tooth	0.75	1										X										
66		subtotal:	13.5	15.5										Nov. 12										
67						Septemb				October				November				Dec	January	February	March	April	May	June
68		Documentation																						
69	D-1	Differential Housing	3	4.5							X				Nov. 16									
70	D-2	Drive Shaft Pin	2	4						X	X													
71	D-3	Internal Gear+Shaft	1.5	3							X	X												
72	D-4	Intenal Diff. Gear	3	2								X	X											
73	D-5	Wheel Hub	2	1.5										X										
74	D-6	Assmebly of Diff.	5	6										X	X									
75		subtotal:	16.5	21																				
76						Septemb				October				November				Dec	January	February	March	April	May	June
77		Weekly Tasks																						

					September	October	November	Dec	January	February	March	April	May	June
77		Weekly Tasks												
78	T1	Met with team	1	1					X					
79	T2	Revised Diff. .dwg	6	6					X					
80	T3	Purchsed Parts	1	2						X				
81	T4	Assembled Differential	4	3						X X				
82	T5	Mnufct. Transmission Hou	2	4						X				
83	T6	Asmbled. Gear Box	1	1						X				
84	T7	Suspension tower Design	1	0.5						X				
85	T8	Chassis Manufactoring	4	6						X X				
86	T9	Assembly Drawing Edits	1	3						X				
87	T10	Drilled Chassis	0.5	1						X				
88	T11	Find All other Mounting Po	2	3						X				
89	T12	Completed Chassis	10	6							X			
90	T13	Assembled RC	2	1							X			
91		subtotal:	35.5	37.5										
92					Septemb	October	November	Dec	January	February	March	April	May	June
93		Part Construction												
94	7a	Differential Cover Print	2	3					X					
95	7b	Gear Box	4	6					X	X				
96	7b	Chassis	10	6						X X X	X			
97	7c	Completed RC	2	1							X			
103		subtotal:	18	16						Feb.				
104					Septemb	October	November	Dec	January	February	March	April	May	June
105		Device Construct												
106	9	Complete Device	N/a	N/a							X			
113					Septemb	October	November	Dec	January	February	March	April	May	June
114		Device Evaluation									Mar. 30			
126					Septemb	October	November	Dec	January	February	March	April	May	June
127		489 Deliverables											May??	
138														
139		Total Est. Hours=	2480	2492										Jun. 10
151														
152														

APPENDIX F – Expertise and Resources

Assistance from professors in the analysis category and SolidWorks design help was needed. Special help was needed from team members for assembly drawing for final assembly. All money spent on this project will come straight from the pockets of the team members and no outside assistance will be given. The team tried to email Traxxas, however they have not given a response, and are likely to not respond anyway.

APPENDIX G – Testing Report

Introduction

The first test performed was the temperature test in which the motors temperature was tested to make sure it didn't reach above 50 degrees C. The aspects of this test that were measured include number of trials, the time of each trial and in-between trials, and again, temp. of the motor. The purpose of this is really to test the gear box that the team designed to see if it would over or underload the motor in anyway that would cause the motor to overheat. This would affect the longevity and functionality of the motor inevitably if it were to be running at such high temps. The prediction is that the car will be able to maintain a temp much lower that this. The prediction and requirement are based off partially the melting point of PLA which is the material that was 3D printed for the transmission housing.

Methods/Approach

Predictions:

- Car will stay under required temperature
- Car will be able to complete all trials without failure

The time will be kept on a stopwatch (apple watch) and then imported to an excel spreadsheet where time and temperature will be recorded to reflect the results of the test.
Resources that will be required to complete this test are as follows:

- RC Batterie
- RC Remote
- RC Car
- Stopwatch
- Digital food thermometer (one from the lab)
- Two lab partners
- Notebook
- Writing Tool

Materials cover everything except the space to perform the test which can take place almost anywhere there is enough space to complete a small circle.
Some of the testing options were:

1. Church parking lot
2. Hogue engineering building inside or out
3. Any of the partners houses

Option 3 was chosen since it was easiest to perform at a home where most of the tools for repair subsided. Since this test needed to be performed with the car traveling at a speed of 10-15mph the entire time it was best that it was done in an open neighborhood away from people and traffic. The ground was chip seal so there was an excessive amount of small rocks all over but this did not effect the performance of the car.
The test took place on a Sunday when all the partners were available to assist with videotaping, measuring, and recording. No part of this test was calculated, the test was done, and data was measured and recorded onto an excel spreadsheet.

Testing Procedure 1: Temperature

Summary

This procedure documents the of recording temperature readings, time it takes for the motor to reach a certain temperature and cool down time. The motor was purchased from a retailer and is "Castle" Brand. It is required to not exceed the temperature of 50 degrees C. The following is the test information and procedure.

Time: This test will be conducted on 4/9/21 from noon to 2:00pm in Hogue in the thermodynamics lab. There will be 35 minutes of collecting equipment before testing begins and less than 30 minutes after for returning equipment as well as 45 minutes total for testing.

Place: Thermodynamics lab, Hogue Hall, Central Washington University in Ellensburg, WA.

Required Equipment Includes:

- RC Batterie
- RC Remote
- RC Car
- Stopwatch
- Digital food thermometer (one from the lab)
- Two lab partners
- Notebook
- Writing Tool

Risk: The test cannot be conducted with the selected batterie to power the device. Risks of the batterie catching on fire or the motor heating up causing the plastic transmission housing to melt would cause the test to fail. Additional helpers are required for this test.

The test procedure is as follows:

1. Collect equipment
    a. Remote
    b. Temperature measuring device from thermodynamics lab in Hogue
    c. Stopwatch on phone
    d. Two partners
2. Go to Thermodynamics Lab in Hogue
3. Place equipment on table
4. Delegate timing and temperature taking tasks to two other people
5. Remove batterie cover on rc and insert batterie, then replace the cover
6. Using the temperature device check the initial temperature of the motor and batterie
7. Using hookups from the speed controller and batterie, connect power to the device
8. Power on the remote by actuating the switch to the on position
9. Power on the device by turning the switch located on the other set of wires connected to the speed control

10. Tell partner 1 to start timing as soon as you give the car throttle input
11. Partner 2 check temperature of motor after 10-minute drive
    a. Repeat steps 11-13 2 more times and start after the car has rested for 5 minutes
12. Partner driving, records data while partner 2 take measurements
13. Return all equipment to its proper place

14. Use data to create an excel spread sheet
    a. Open excel and save as (*Test1_RCTemp)*
    b. Create a table with 4 rows and 3 columns labeling the right most columns “time” and “temp”, and the columns “trial 1”, “trial 2”, etc.
    c. Import data to spreadsheet
    d. Screenshot the table and crop so that only the table is visible

Deliverables

Starting off the car performed well and was under temperature by a long shot; however, the second test did not go so well. The operator accelerated the car too quickly and caused the differential housing to strip from its bolts. This was fixed quickly with super glue just to fill the void where there was now a lack of threading for the screw to go into. The third trial then started a bit later than was expected for the 5-minute break that was allotted. This is noted in the TDR1 in appendix G as well stating that the differential was not sufficiently infilled, so the screws never really had any material to thread into causing it to strip easily. This was then fixed by reprinting and then prematurely filling the differential housing with epoxy so that the screws would then have something to thread into.

Introduction

This test is for the acceleration of the car within a given distance. Measurements that will be taken include the distance of the track, time it takes the car to complete the track and how fast the car was going at max speed by the end of the track. The "track" will be a straight line being 30ft long with a timer at the end to achieve an exact time stamp. The car will have a phone with a GPS speedometer app open to track the speed in miles per hour. The primary intention of this test is to gather accurate measurements of the top speed and time it took so that the acceleration of the car can be calculated. There will be no specific type of surface as a requirement for this test unless the surface chosen is seen as the issue for producing inconsistent or unsatisfactory results.

The predictions for this test were that the car would in fact be able to reach a speed of 30mph withing the allotted 30ft. This was based on the motor's capability paired with the battery, and including the gear up designed by the team.

Methods/Approach

Predictions

- Car will be able to reach a speed of 30mph
- 30mph will be achieved in 30ft starting from standstill

Since the speed will be measured in miles per hour from the phone GPS, a table will be created in excel to convert that to a velocity and acceleration in ft/s and ft/s^2. This will not show us an accurate acceleration since the acceleration isn't completely linear so an average will be taken to improve that accuracy slightly. In the end however the test is named the "acceleration test" but it truly a test to see if the car will be able to reach a certain speed in a certain distance.

Certain tools that will be needed are as follows:

- RC Batterie
- RC Remote
- RC Car
- Stopwatch
- 40ft of free space
- Tape or cones
- Two lab partners
- Notebook
- Writing Tool

These materials cover everything that will be used during the test including space for the test, a recording device for the data readings, and the tools to gather data with. It is preferable that the test be done in a more open environment so that the car will not crash immediately if it is incorrectly maneuvered just a small amount. It is also important to be safe when doing the experiment. A larger testing area could ensure more of a barrier if there happen to be people walking by as the test did end up being performed outside on school grounds.

Some testing options for this were:

- Any of the three partners streets near their house
- Any open parking lot or patio on campus
- Church parking lots since they are usually empty during the weekdays
- Inside The engineering building Hogue

The time of the test, which took place at 11:00am was only two hours before each of the partners had lab, was really the determining factor. The back patio of Hogue provided enough length and a good safe amount of width that the course could be created on while still providing gave buffer from the public. The surface happened to be poured concrete which makes for a nice and course surface, so traction was not an issue.

Testing Procedure 2: Acceleration

Summary

This procedure documents the recording of speed and time readings from a 30 ft track. The motor was purchased from a retailer and is “Castle” Brand. It is required that the car reach a speed of 15mph within this 30ft. The following is the test information and procedure.

Time: This test will be conducted on 4/27/21 from 11:00am to 12:30pm on the back patio of Hogue. There will be 5 minutes of collecting equipment before testing begins and less than 5 minutes after for returning equipment as well as 60 minutes total for testing.

Place: Hogue Hall back patio0, Central Washington University in Ellensburg, WA.

Required Equipment Includes:

- RC Batterie
- RC Remote
- RC Car
- Stopwatch
- 40ft of free space
- Tape or cones
- Two lab partners
- Notebook
- Writing Tool

Risk: The test cannot be conducted with the selected batterie to power the device. Risks of the batterie catching on fire or the motor heating up causing the plastic transmission housing to melt would cause the test to fail. Additional helpers are required for this test.

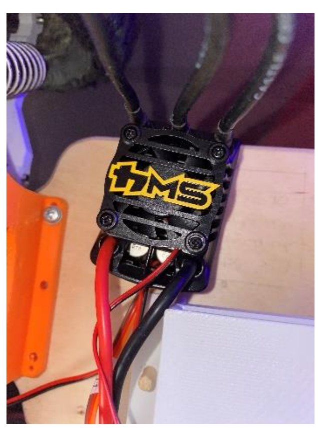
The test procedure is as follows:

15. Collect equipment
    a. Remote
    b. Temperature measuring device from thermodynamics lab in Hogue
    c. Stopwatch on phone
    d. Two partners
16. Go to back side of Hogue
17. Place equipment on ground
18. Delegate timing to two people and have them stand at either end of the start and finish line
19. Remove batterie cover on rc and insert batterie, then replace the cover

20. Using hookups from the speed controller and batterie, connect power to the device

21. Power on the remote by actuating the switch to the on position

22. Power on the device by turning the switch located on the other set of wires connected to the speed control



23. Tell partner 1 to start timing after their agreed upon count down

24. Car should be driven as fast as possible from one side to the other without deviating more than 5ft from a straight line
25. Partner 2 should start their timer at the same time and stop it when it reaches the other side
    a. Repeat steps 9-11 2 more times
26. Partner 1 records data while partner 2 reads measurements
27. Return all equipment to its proper place
28. Use data to create an excel spread sheet
    a. Open excel and save as (*Test2_RCAccel)*
    b. Create a table with 5 rows and 7 columns labeling the right most columns "Battery voltage" and following to the right: Trial, Initial V(ft/s), Distance (ft), Time (s), Final V(ft/s), Acceleration (ft/s^2).
    c. Import data to spreadsheet and complete necessary calculations
    d. Screenshot the table and crop so that only the table is visible
    e. Paste the table into the senior project report in the testing appendix section

Batterie Volt (V)	Trial	Initial V (ft/s)	Distance (ft)	Time (s)	Final V (ft/s)	Acceleration (ft/s^2)
7.4	1	0	30	2.68	11.19402985	4.17687681
7.4	2	0	30	2.91	10.30927835	3.542707337
7.4	3	0	30	2.42	12.39669421	5.122600915

Deliverables

On the first test the car collided with the wall and tore the A-arm from the chassis mounting point. This was repaired and progress went as planned after that. Testing was completed with fluidity in the time frame provided. The car originally was met to reach a speed of 30mph within the 30ft distance. This was a test based off previous knowledge and the stats of how the motor should perform. The distance was not great enough to reach this speed from a stand still. The results were as follows, the first and third test his 18mph and the second test only 16. The throttle input reached maximum at about half the distance of the track which was needed to control the car successfully. The data shows that the acceleration of the car was the highest at 5.12 ft/s^2 assuming that the car was going its fastest at the end of the track and it was a linear acceleration which it was not, so there will be some discrepancies in the calculations there. Each of the trials data were recorded by two of the other partners and then imported to the excel table shown to be converted. As a side note, the measurements were taken in miles per hour for the speed but are not present on the table. This is because one of the partners calculated what it would be in ft/s before the numbers were moved over to excel to save time and effort.

Introduction

Third and final of the test consists of simply testing the differential to see if it was working properly. This test includes a basic "PASS/FAIL" grading system that was made into a table in excel. The purpose of this test was to see if the car had met its one basic requirement of the entire project being that it has a manufactured working differential. This test did require multiple partners to help complete. The test grade "PASS" would require the rear wheels to: A. Have the ability to spin independently of one another. B: Be able to spin the opposite direction at the same time. The test grade "FAIL" would be anything such as the wheels having to spin together and in the same direction.

Methods/Approach

Predictions

- Wheels will be able to spin independently of one another and spin in different directions at the same time.

Two partners will be used to secure the car and to also take down notes so the driver can focus on driving. By doing this, all the tests can be completed in a rapid fashion. One of the tests will be holding one wheel while giving input and seeing of it will spin. The other is to spin one side clockwise and seeing if the other side will spin the opposite direction.

There was no discussion as to where the test was going to take place because all of the partners were already attending class in Hogue at the time, so it was done in the common area.

Procedure

Testing Procedure 3: Differential Functionality

Summary

This procedure documents the recording of "PASS OR FAIL" for the functionality of the drive train. The motor was purchased from a retailer and is "Castle" Brand. It is required that the drive train allow independent rotation of the wheels to achieve PASS. The following is the test information and procedure.

Time: This test will be conducted on 5/5/21 from 6:00pm to 6:30pm on the kitchen tables in Ryders dining room. There will be 5 minutes of collecting equipment before testing begins and less than 5 minutes after for returning equipment as well as 15 minutes total for testing.

Place: Ryders house, Ellensburg, WA.

Required Equipment Includes:

- RC Batterie
- RC Remote
- RC Car
- Two lab partners
- Notebook
- Writing Tool
- Table

Risk: The test cannot be conducted with the selected batterie to power the device. Risks of the batterie catching on fire or the motor heating up causing the plastic transmission housing to melt would cause the test to fail. Additional helpers are required for this test.

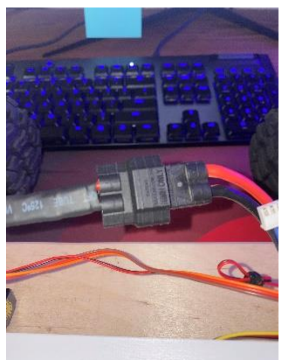
The test procedure is as follows:

29. Collect equipment
    a. Remote

b. Temperature measuring device from thermodynamics lab in Hogue
c. Stopwatch on phone
d. Two partners

30. Go to Ryders dining table
31. Place equipment on table
32. Delegate recording to one person and holding the RC to the other
33. Remove batterie cover on rc and insert batterie, then replace the cover

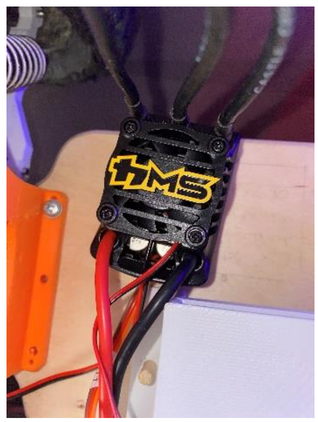
34. Using hookups from the speed controller and batterie, connect power to the device



35. Power on the remote by actuating the switch to the on position

36. Power on the device by turning the switch located on the other set of wires connected to the speed control

37. Tell partner 1 to hold the rear end of the car off the ground while holding one of the two rear tires in place
38. Have the driver give a small amount of input to the throttle just in case it would fail, this could possibly injure the partner holding the car, do this only until it is evident that the other wheel is able to spin without the other
    a. Repeat steps 9&10 one more time with the other wheel
39. Using only one partner, have the rear end free and rotate just one any direction and observe to see if the other spins the opposite way
40. Partner 1 records data while partner 2 reads measurements
41. Return all equipment to its proper place



42. Use data to create an excel spread sheet
    a. Open excel and save as (*Test3_RCDifferential)*
    b. Create a table with 1 row and 2 columns labeling the right most column "Pass/Fail"
    c. Import data to spreadsheet
    d. Screenshot the table and crop so that only the table is visible
    e. Paste the table into the senior project report in the testing appendix section

Pass/Fail	Pass

Deliverables
The car passed this test with ease and there were no issues or complications that went along with this test. The differential performed as it was supposed to and the car withstood the tests.

APPENDIX H – Resume

Ryder Satak

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https://www.linkedin.com/in/ryder-satak/

EDUCATION

CENTRAL WASHINGTON UNIVERSITY | MECHANICAL ENGINEER

MECHANICAL ENGINEERING AND TECHNOLOGY (ABET Accredited) Sep. 2017 - June 2021
Bachelor of Science in Mechanical Engineering and Technology GPA: 3.251
Mathematics Minor
Relevant Coursework: Machining, Metallurgy, Auto CAD and Solid Works 3 D CAD Design

PROJECTS

CENTRAL WASHINGTON UNIVERSITY, MECHANICAL ENGINEERING AND TECHNOLOGY Sep. 2017 - Dec. 2017
Personal Design Project – Solid Works

- Designed a working car jack with moving parts and 10 personally designed parts total
- Gained vital experience in multiple ways to do one job

Personal Design Project – Technical Writing

- Accurately created a set of instructions that detained the construction process of an aircraft
- Hands on with a new material and had to figure out its strength and weaknesses
- Designed and constructed a working Control Line Airplane from balsa wood

EXPERIENCE

TAYLOR SHELLFISH June 2019 – Present
Geoduck Farmer/Harvester

- Implemented the use of timetables and geographic math to establish optimal works hours and maximize efficiency
- Consistently exceed production goals which results in a 14% increase in collaborative bonus
- Efficiently work with 8 other employees to streamline productivity

SOUTH MASON YOUTH SOCCER CLUB Sept. 2011– Present
Soccer Referee

- Maintained physically safe environment for player and parents in accordance with WSRC regulations
- Officiated game while maintaining an unbiased point of view
- Diffused hostile situations between teams to ensure safety
- Overcame mental age gap to relate to younger teams
- Refereed a wide variety of age ranging from 8 to 32

CWU DINING SERVICES (NORTH VILLAGE CAFÉ) Sept. 2017 – Present
Food Worker

- Collaborated with other employees to maintain a clean and safe work environment
- Actively process and complete orders to ensure fluidity
- Provided customers with accurate and precise orders
- Increased sales by 11% in my station

ACHIEVEMENTS/QUALIFICATIONS

- Certified in Microsoft Office (Spring 2018)

- National Honors Society (2017-present)
- Dean's list: Awarded to students who have GPA 3.0 or higher each quarter (2017-present)
- AutoCAD Certified (Fall 2018)
- Fully trained for a diverse group of machinery
- Mechanical Engineering and Technology undergraduate student with completed pre-requisites
- Member of ALPHA